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South Sandstone
Creek Dam, Plevna,
Montana, Fallon
County, MT 02005

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

SOUTH SANDSTONE CREEK DAM
PLEVNA, MONTANA
FALLON COUNTY
MT 02005

prepared for:

HONORABLE TED SCHWINDEN
GOVERNOR, STATE OF MONTANA

SOUTH SANDSTONE RECREATION AND
WATERSPREADING GROUP
(OWNER-OPERATOR)

MONTANA DEPARTMENT OF FISH, WILDLIFE AND PARKS
(JOINT-OPERATOR)

prepared by:

HKM ASSOCIATES
BILLINGS, MONTANA

APRIL 1981

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Appendix F - Correspondence
- Montana Department of Fish, Wildlife and Parks
  - Comments on Draft Report
- Montana Department of Natural Resources and Conservation
  - Comments on Draft Report
- U.S. Soil Conservation Service Comments on Draft Report

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EXECUTIVE SUMMARY

Personnel of HKM Associates, under a contract with the Montana Department of Natural Resources and Conservation (DNRC), and with representation from the DNRC, the U.S. Soil Conservation Service (SCS), the Montana Department of Fish, Wildlife and Parks, and the South Sandstone Recreation and Waterspreading Group, inspected South Sandstone Creek Dam on September 27, 1979. The inspection and evaluation were performed under the authority of Public Law 92-367. South Sandstone Creek Dam is located on South Fork Sandstone Creek, approximately 5.5 miles southeast of Plevna, Fallon County, Montana. Construction of the project was started in March 1975 and completed in November 1975.

FINDINGS AND EVALUATION

South Sandstone Creek Reservoir stores runoff from a drainage of 48 square miles. There are other small storage ponds in the upstream watershed, but none of significant size. The reservoir feeds downstream irrigation delivery systems as well as South Sandstone Creek.

South Sandstone is a multi-purpose project as the stored water is used primarily for waterspreading and recreation, and secondarily for floodwater detention and sediment accumulation. Reservoir capacity to the principal spillway crest (stoplogs in place) is 880 acre-feet (AF), 1510 AF to the emergency spillway crest, and 1970 AF to the design dam crest control elevation (Ref. 1). The dam has a hydraulic height of 38 feet and a structural height of 47 feet. On the basis of criteria in the U.S. Army Corps of Engineers' Recommended Guidelines for Safety Inspection of Dams (Ref. 2), the project is intermediate in size. Based on a visual inspection and engineering judgment there are at least 5 inhabitable structures in the flood plain downstream of South Sandstone Creek Dam located such that a dam failure could endanger many lives and cause significant property damage. The downstream hazard potential for this storage project is therefore high (Category 1).

The guidelines recommend that the spillway design flood for an intermediate-size, high downstream hazard potential dam be the Probable Maximum Flood (PMF). The PMF is defined as a flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. Routing of the estimated PMF developed for the safety evaluation of South Sandstone Creek Dam showed that the dam is first overtopped when about 8 percent of the PMF volume enters the reservoir. However, the valley upstream of the dam is very wide and there is considerable opportunity

for natural storage along the stream channel which would reduce the magnitude of the PMF at the reservoir. Therefore, the dam would likely overtop during the PMF when more than 8 percent of the PMF volume enters the reservoir, but we believe the project cannot handle ½ PMF. The SCS designed the project for a little more than a 100-year flood, which is considerably smaller than ½ PMF. The detailed studies required to accurately analyze this drainage basin are beyond the scope of work for this Phase I study and should be addressed in future work. The dam embankment materials are classified as being moderately erodible and can be expected to remain stable only for a short period of time under an overtopping condition. A failure could possibly endanger the lives of many people and will cause significant property damage. Based on this Phase I level investigation, the project is incapable of handling a flood having one-half the PMF volume without overtopping leading to dam failure. Therefore, according to inspection guideline criteria, the South Sandstone Creek Dam has a seriously inadequate spillway and is considered unsafe, nonemergency until the recommended actions have been taken.

The South Sandstone Creek Dam embankment appears to be stable and in good condition, except for the stability of the structural fill behind the principal spillway chute. The fill has experienced substantial settlement and erosion, resulting in broken drain lines where they pass from the backfill through the chute wall. These broken lines will transmit water through the chute walls when the spillway is flowing, resulting in backfill erosion and possible damage to the spillway. There is insufficient geotechnical infomation available to fully evaluate the embankment stability.

RECOMMENDATIONS

Due to storage between normal pool and dam crest, the present project provides a degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing this existing flood protection.

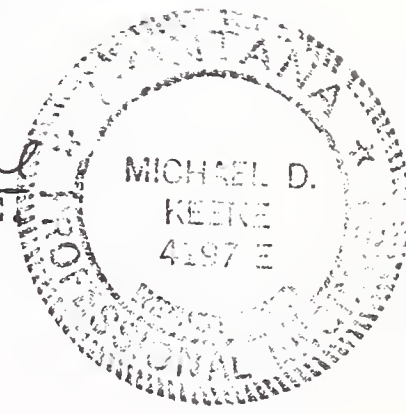
Immediately develop, implement, and test a downstream warning plan, and implement a more active operation and maintenance program. Miscellaneous rehabilitation and maintenance should be performed in the following areas: on the principal spillway where concrete repair is required, the structural backfill behind the chute walls and the local subsurface drains require immediate repair, and the earthen slopes in the stilling basin need stabilization; on the diversion structure where regrading of the entrance slope and placing riprap is necessary, debris removal is required, conduit joints and grade need repair and/or adjustment, and the outlet requires repair and protection; on the upstream

embankment slope where wave action has cut nearly vertical slopes; and along the dam crest, particularly along the west section where fill and regrading is required. A regular program should be developed to monitor future settlements, potential seepage, and erosion with special emphasis during periods of high reservoir levels. Also, an emergency plan should be formalized which addresses the method and procedures for more completely draining the reservoir pool. Install piezometers and use the data for a stability analysis. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity. Modify the project as studies indicate.

Prior to performing engineering studies and/or remedial construction, coordinate the work with the State of Montana Department of Natural Resources and Conservation.

Mike Keene

Michael D. Keene, P.E.



PERTINENT DATA SUMMARY

1. General

Federal ID Number	MT 02005
Owner and Operator	South Sandstone Recreation and Waterspreading Group
Joint-Operator	Montana Department of Fish, Wildlife and Parks
Purpose	Waterspreading and Recreation
Location	Section 29, T7N, R58E, MPM
County, State	Fallon County, Montana
Watershed	Coon Creek and South Fork Sandstone Creek
Drainage Area	48 square miles
Hazard Potential	Category 1 (High)
Size Classification	Intermediate

2. Reservoir

Surface Area at Principal Spillway Crest Elevation (Stoplogs in Place) 2856.65 feet NGVD (See note on page ix)	119 acres
50-Year Sediment Storage	240 acre-feet
Storage to the Diversion Structure Inlet Elevation (No Stoplogs) 2855.5 feet NGVD	750 acre-feet
Inlet Elevation (Stoplogs in Place) 2857.0 feet NGVD	920 acre-feet
Storage to Principal Spillway Crest Elevation (No Stoplogs) 2855.15 feet NGVD	710 acre-feet

PERTINENT DATA SUMMARY
(Continued)

Crest Elevation (Stoplogs in Place) 2856.65 feet NGVD	880 acre-feet
Storage to Emergency Spillway Crest Elevation 2860.7 feet NGVD	1510 acre-feet
Current Maximum Storage Capacity Before First Overtopping Dam Crest Elevation 2862.75 feet NGVD	1920 acre-feet
Storage to Design Dam Crest Control Elevation 2863.0 feet NGVD	1970 acre-feet
Reservoir Water Surface Elevation on the Day of Inspection 9/27/79	2852.0 feet NGVD

3. Emergency Spillway

Crest Elevation	2860.7 feet NGVD
Type	Unregulated, Broad Crested, and of Earthen Construction
Shape	Trapezoidal
Width	280 feet
Side Slopes	1V on 2.4H on left (west) side 1V on 4H on right (east) side
Spillway Capacity (To First Overtopping Dam Crest Elevation)	1700 cubic feet per second
Spillway Capacity (To Dam Crest Control Elevation)	2050 cubic feet per second

4. Principal Spillway

Type	Concrete Drop Inlet and Chute

PERTINENT DATA SUMMARY
(Continued)

Uncontrolled Crest Elevation (Bottom of Notch Sections)	2855.15 feet NGVD
Controlled Crest Elevation (Stoplogs in Place)	2856.65 feet NGVD
Shape	Rectangular
Width	20 feet
Spillway Capacity (To First Overtopping Dam Crest Elevation)	3550 cubic feet per second
Spillway Capacity (to Design Dam Crest Control Elevation)	3800 cubic feet per second

5. Diversion Structure

Gates	Two 48-inch x 48-inch Slidegates
Control	Manual Operators
Conduit	Twin 48-inch Diameter Concrete
Length	72 feet
Capacity	
To Principal Spillway Crest (With Spillway Stoplogs in Place)	67 cubic feet per second
To First Overtopping Dam Crest Elevation	418 cubic feet per second
To Design Dam Crest Control Elevation	424 cubic feet per second

6. Dam

Type	Zoned Earth Fill
Structural Height	47 feet
Hydraulic Height	38 feet

PERTINENT DATA SUMMARY
(Continued)

Design Crest Control Elevation	2863.0 feet NGVD
First Overtopping Dam Crest Elevation	2862.75 feet NGVD
Total Crest Length	2908 feet
Design Crest Width	
Dam	30 feet
Dike	15 feet
Design Upstream Slope	1V on 2¼H; 1V on 3H; 1V on 4H
Design Downstream Slope	1V on 2½H

Note: Reference datum for survey dated 10/10/79 was the diversion structure design inlet elevation of 2855.5 feet NGVD.

CHAPTER 1
BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority

This report summarizes the Phase I inspection and evaluation of South Sandstone Creek Dam. The project is owned by the South Sandstone Recreation and Waterspreading Group (SSG). Project operation and maintenance is shared by the SSG and the Montana Department of Fish, Wildlife and Parks (MDFWP).

The National Dam Inspection Act, Public Law 92-367 dated August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam
(2) based upon an evaluation of the available data and a visual inspection
(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted
(4) not intended to include extensive explorations, analysis, or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana, Department of Natural Resources and Conservation (DNRC). It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act, shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose and Inspection

The findings and recommendations in this report were based on visual inspection of the project, minimal field survey measurements, and a review of available design and operation data. The purpose of the inspection was to make a general assessment as to the structural integrity and operational adequacy of the dam embankment and its appurtenant structures. Inspection procedures and criteria were those established by the Recommended Guidelines for Safety Inspection of Dams (Ref. 2).

The visual inspection of South Sandstone Creek Dam was made on September 27, 1979. HKM Associates personnel who attended the field inspection and contributed to this report were:

Dan Dyer, Geotechnical Engineer
Mike Keene, Hydraulics/Hydrology, Team Leader

Other HKM personnel contributing to the report but not attending a field inspection were:

Dale R. Cunnington, Structural Engineer
Gary Elwell, Hydraulics/Hydrology
Dan Nebel, Geology

Other personnel present during the September 27, 1979 inspection included:

Glen McDonald, Supervisor, Montana DNRC Dam Safety Section
Art Taylor, Dam Safety Engineer, Montana DNRC Dam Safety Section
John Dalton, U.S. Soil Conservation Service, (SCS)
Ken Pfeiffer, SCS
Keith Seaburg, MDFWP
Dave Conklin, MDFWP
John Ramsey, MDFWP
Robert Rieger, SSG
Matt Thielen, SSG

A field survey was performed by an HKM Associates survey crew on October 10, 1979. The purpose of the survey was to obtain a profile along the dam crest and hydraulic structure elevation measurements, for verification of as-constructed conditions and to observe project changes.

It was stated by the agency representatives that the project is inspected annually by the MDFWP and by the local water users, and occasionally by the SCS. Inspection and maintenance reports were not available for review.

The investigation process allows for report review by: the Montana DNRC; the SCS; the SSG; and the MDFWP. Review comments are considered before final publication of the Phase 1 Inspection Report. Comments from the MDFWP, the Montana DNRC and the SCS are attached in Appendix F. The owner did not wish to respond.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

South Sandstone Creek Dam is a compacted earth fill dam located in the N½ of Section 29, T7N, R58E, M.P.M., Fallon County, Montana (Appendix A and Ref. 3).

The storage project contains flow from Coon and South Fork Sandstone Creeks, and forms a multi-purpose facility within the Missouri River Basin. Storage water is either released

into a waterspreading distribution system or returned to South Fork Sandstone Creek. The nearest downstream community is Plevna, Montana, which is located approximately 5.5 miles north-northwest of South Sandstone Creek Dam (Appendices A and B, and Photo 8 of Appendix C).

Project operation and maintenance is shared by the SSG and the MDFWP. The SSG has sole responsibility for maintaining the diversion structure. The MDFWP is solely responsible for the operation and maintenance of the fish management and recreation portion of the project. Jointly the two groups share operating responsibility for the diversion structure, and are both responsible for the operation and maintenance of the dam and spillways (Ref. 1).

South Sandstone Creek Dam has a hydraulic height of 38 feet and impounds approximately 1920 acre-feet (AF) at the first overtopping dam crest elevation (elevation 2862.75 feet NGVD, see note on page ix). Based on a visual reconnaissance and engineering judgment, there is 1, and possibly 2, farmstead(s) located in the flood plain between the dam and Plevna, and at least 4 residences in the flood plain downstream of Plevna. In addition to inhabitable structures, there are private and county roads, bridges, utility lines, and agricultural land that will be affected by a sudden breach of the dam. On the basis of this information and in accordance with the Recommended Guidelines (Ref. 2), the project is classified intermediate in size and the downstream hazard potential is high (Category 1).

South Sandstone Creek Dam has two spillways, principal and emergency, and a diversion structure. The principal spillway is a concrete box inlet, rectangular chute spillway having a width of 20 feet and an estimated capacity to the first overtopping dam crest elevation of 3550 cubic feet per second (cfs). The emergency spillway is a 280-foot wide trapezoidal earth section with an estimated capacity of 1700 cfs to the first overtopping elevation. The diversion structure for South Sandstone Creek Dam supplies water to the irrigation delivery canal via twin 48-inch diameter concrete pipes. Maximum outflow capacity for the diversion structure to the first overtopping dam elevation is 418 cfs. There is no low-level outlet for the South Sandstone Creek Dam.

South Sandstone Creek Dam was constructed primarily to enhance downstream waterspreading practices and to provide recreational benefits. Incidental capacity is provided for sediment accumulation and floodwater detention. Storage to the normal pool level, or the inlet to the diversion structure (elevation 2855.5 feet NGVD), is 750 AF. From the normal pool level to the existing low point on the dam

crest, there are 1170 AF available for flood surcharge storage.

South Sandstone Creek Reservoir has an upstream contributary drainage area of 48 square miles. The watershed is classified basically as a prairie drainage with an elevation change of approximately 500 feet from the basin divide to the dam, a distance of about 10 miles. The reservoir is located primarily in open range country with occasional small drainage coulees and bluffs (Photos 1-7).

1.2.2 Regional Geology

South Sandstone Creek Dam is situated in the Great Plains Province on South Fork Sandstone Creek in a subdued topography of broad undulating plains with scattered high buttes. The dam is located on the nearly flat-lying sediments of the Fort Union formation (Tertiary) off of the west flank of the Cedar Creek anticline. No faults, either recent or ancient, have been noted in the dam area. The strata in the area consists of nearly flat-lying, soft shale beds with some sandy layers.

1.2.3 Seismicity

South Sandstone Creek Dam is in a relatively quiet seismic zone with the majority of the region's seismic events occurring in the southwestern Montana-Yellowstone Park area. Since 1925, Montana has experienced five shocks that reached intensity VIII or greater (Modified Mercalli Scale). The closest epicenter occurred at Helena, Montana which is approximately 300 miles west of the damsite. No shocks of intensity IV or greater have been reported within a 100-mile radius of the site (as of January, 1974). The dam is located in Zone 1 of the Seismic Zone Map of the Contiguous States as shown in Reference 2. The seismic probability of Zone 1 is one of minor damage and is based on known distribution of damaging earthquakes and their associated intensities. In general, dams in seismic Zone 1 may be assumed to present no hazard from earthquakes provided static stability conditions are satisfactory and conventional safety margins exist (Ref. 2, 4).

1.2.4 Site Geology

The Soil Conservation Service explored the South Sandstone Creek Damsite in April, 1972. Location and logs of soil borings are presented on Sheets a and h of Exhibit D1, Appendix D. The dam is located in a generally shaly section of the Fort Union formation. South Fork Sandstone

Creek has incised itself about 50 feet below the surrounding highlands and has formed a broad level valley floor with associated terraces on the valley walls. The foundation in the valley floor consists of 5 to 9 feet of weak saturated silty sands and clays underlain by alluvial sands and gravels to a total depth of 5 to 26 feet. The sand and gravel overlie shale bedrock. The core trench extends into shale (Exhibit D1 and Ref. 1).

Both abutments are founded in a large terrace. The left abutment terrace is composed of semi-consolidated clays, silts, sands and gravels underlain by impervious, competent shale at a depth of about 5 to 16 feet. The right abutment terrace is similar, but much less pronounced with the overlying semi-consolidated materials reaching a maximum depth of only about 5 feet. The core trench extends into the impervious shale beneath both abutments. The diversion structure conduits are located in the left abutment and are underlain by compacted fill. The principal spillway is a concrete structure underlain by compacted fill and is located in the embankment. The emergency spillway is located on the right (east) side in terrace materials.

1.2.5 Sedimentation

The catchment area above South Sandstone Creek Reservoir consists primarily of natural grass-covered range land with some subirrigated lands. Project correspondence, dated January 21, 1971 and issued by Mr. Eddie Juvan, a SCS geologist, estimated that the sediment yield from the watershed would be moderately low. It was suggested that a rate of 0.1 AF per square mile per year would be adequate, which is equivalent to a 50-year sediment storage requirement of 240 AF (Ref. 1). A survey transect has been established to monitor sediment accumulations in the pool, but has not yet been put to use.

1.2.6 Design and Construction History

South Sandstone Creek Dam was designed by the Soil Conservation Service. Construction was financed with a combination of funds from local, county, state, and federal sources. More specifically, the sources include: local funding by the South Sandstone Group; county funding by Fallon County; state funding by the Montana Department of Fish, Wildlife and Parks; and federal funding by the Soil Conservation Service. Rehbein Contracting, Inc. of Plains, Montana was the construction contractor. Project construction started in the Spring of 1975, and reached completion in November 1975 (Ref. 1).

Information relative to project history, design, and construction of South Sandstone Creek Dam was very limited. Construction and "as-built" drawings were reviewed, with some reproductions of the construction drawings provided in Exhibit D1 of Appendix D. A complete set of drawings is available in the Bozeman, Montana office of the SCS. It was noted in the SCS "work plan" file that: 42 test holes were made in the embankment area at the time of design; 12 test holes were made in the borrow areas; and the lab analyses included Atterberg Limits, grain size distribution, moisture-density relationships, and specific gravity tests. There was no indication that triaxial shear, direct shear, or field permeability tests were performed. Also included in the "work plan" file was hydrologic design criteria, numerous runoff hydrographs and flood routing trials, and some calculations associated with the hydraulic structural design. It became obvious after cross-referencing work plan information with the "as-built" drawings, that the available hydrologic and hydraulic data in the "work plan" file is not final or complete.

The project files indicate that South Sandstone Creek Dam was originally classified by SCS Design Memorandum No. 27 criteria as Class A - Low Hazard. By that criteria, a storm approximating the 100-year 6-hour rainfall was used to develop the spillway design flood (SDF).

The available records indicate that no significant repair and/or improvement work has been performed since construction completion in November 1975. Project owners and operators verified this during the field investigation.

CHAPTER 2
INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillways

South Sandstone Creek Dam has two spillways. A concrete-lined principal spillway is located a considerable distance away from the left abutment and is on the embankment, and a grass-lined earth emergency spillway is positioned on the right (east) side of the dam.

2.1.1.1 Principal Spillway

The principal spillway is a concrete structure, located on the dam embankment, consisting of a box inlet, chute section, and a stilling basin (Sheets e and f of Exhibit D1). The inlet elevation can be controlled by the use of stoplogs in two openings of the box inlet. Each opening has the dimensions of 5.5 feet wide and 1.5 feet high, and has an existing minimum control elevation (without stoplogs) of 2855.1 feet NGVD and maximum control elevation (with stoplogs) of 2856.6 feet NGVD (see note on page ix). Above elevation 2856.6 feet NGVD, the perimeter of the box inlet acts as a sharp-crested weir. There is a maximum drop of almost 8 feet from the spillway inlet elevation to the channel floor. The channel is rectangular in shape with a base width of 20 feet. The channel extends approximately 70 feet horizontally from the box inlet to the beginning of the steep chute. The chute extends approximately 90 feet at slopes of 0.2209 and 0.333 before entering the stilling basin. The stilling basin is concrete with baffle blocks, with a natural pool immediately downstream of the concrete section (Photo 20 of Appendix C). Flows return to the natural channel at the stilling basin outlet (Photo 9). A county road bridge crosses the spillway approximately 12 feet above the spillway floor (Photos 10, 11, 13 and 14). The largest flood, since the dam was completed, occurred in 1978 when approximately one foot of water flowed over the principal spillway (1 foot above one 4-inch stoplog, or reservoir elevation 2856.5 feet NGVD).

Considering its recent construction, the principal spillway structure is appraised as being in relatively poor condition. The spillway is approximately 0.35 of a foot low relative to the plans, and the concrete is cracked on the outside edge of both stoplog sections (Photo 15). The MDFWP indicates that the spillway is low due to settlement at the time of construction or a con-

struction error (Correspondence, Appendix F). There is a small leak at the base of the drop inlet wall, with water seeping into the spillway at the wall-to-floor joint (Photos 12 and 16). Concrete at the top of the right (east) vertical spillway wall under the bridge is cracking and spalling. The cracking appears to be the result of stress concentrations from the bridge (Photo 17). Cracks are evident in the backfill around the principal spillway due to localized soil settlements. The problem is enhanced by the fact that surface runoff is directed towards the chute walls (Photo 18). Large holes or gaps have developed between the backfill and the walls due to settlement and water movement (Photo 19). Several of the drain pipes, intended to relieve local subsurface drainage from behind the walls, have been damaged and displaced at the wall connection (Exhibit D5 of Appendix D). Minor sloughing of the banks is occurring in the stilling basin as shown in Photo 20. There is no riprap protection in the stilling basin.

The chute walls have adequate height to contain the discharge resulting when the reservoir pool is at the first overtopping elevation. However, due to the poor condition of the spillway, high discharges may endanger the dam embankment.

Principal spillway hydraulic rating computations were obtained from the SCS "work plan" file (Ref. 1). Computations were performed using techniques presented in the SCS National Engineering handbook (Ref. 5). Complete principal spillway rating data is provided in Exhibits E3 and E4 of Appendix E.

2.1.1.2 Emergency Spillway

The emergency spillway is an earthen, broad-crested, uncontrolled channel section (Sheet d of Exhibit D1). The channel is trapezoidal in shape with a base width of 280 feet and side slopes of 1V on 2.4H on the left (west) side and 1V on 4H on the right (east) side. Earthern dike sections contain the spillway section, with the flowline being constructed primarily on Zone I earthfill and covered with sod and surface soil (Photo 21). The channel extends approximately 400 feet on a horizontal slope from the inlet to the brink of the broad crest. The channel continues approximately 185 feet further downstream at slopes of 0.020 and 0.001 before transitioning to natural terrain. From there, the spillway discharge travels primarily as overland flow until returning to the South Sandstone Creek flood plain. The spillway crest elevation was designed to be at elevation 2860.5 feet NGVD, but was measured to be 2860.7 feet NGVD during the field survey of October 1979 (see note on page ix).

The emergency spillway has not operated since construction. The channel is in excellent condition with a dense stand of vegetation (Photo 21).

There do not appear to be any conditions that would reduce maximum spillway capacity. The tail dikes appear to be adequate to protect the dam embankment.

Hydraulic rating computations in the SCS "work plan" file (Ref. 1) were based on a channel width of 250 feet, whereas the plans indicate a width of 280 feet. Therefore, new hydraulic rating information was developed using the U.S. Army Corps of Engineers computer program HEC-2 (Ref 16). Calculations were performed assuming spillway flows pass through critical depth at the brink of the control section, a Manning's "n" of 0.03, and the return channel slope is steep enough to prevent backwater effects. Form losses were accounted for. Spillway capacity to the design dam crest control elevation (2863.0 feet NGVD) is 2050 cfs. Complete emergency spillway rating data is provided in Exhibits E3 and E4 of Appendix E.

2.1.2 Diversion Structure

The diversion structure for South Sandstone Creek Dam is located about 1150 feet from the left (west) abutment. The diversion structure consists of an intake structure, twin 48-inch diameter pipes, an outlet structure, and an irrigation water delivery canal. Construction details are shown on Sheet g in Exhibit D1 of Appendix D.

The intake structure is a concrete box inlet with provision for stoplogs 16.5 feet long by 1.5 feet high. The minimum crest elevation is 2855.5 feet NGVD (see note on page ix). A trash rack consisting of 2-inch bars on 12-inch centers is placed over the inlet (Photos 30 and 31). Basically, the intake structure is in good physical condition. The two slidegates were not operated during the inspection, but project representatives indicate them to be fully operable. One minor problem at the inlet involves the accumulation of gravel and debris at the bottom of the drop (Photo 30).

The outlet conduits are twin 48-inch diameter reinforced concrete pipes (RCP). Total conduit length from the intake structure to the outlet structure is 72 feet. Patchwork was not completed on the exposed concrete aggregate of the east conduit near the slidegate (Photo 25). Standing water in the conduits of the diversion structure is a result of some settlement and accumulation of debris (Photos 24 and 28). The left (west) diversion conduit shows horizontal misalignment (Photo 28). Neither of the diversion structure conduits appear to have sealant at the joints, the joints are separated more than the .75 inches generally permissible for 48-inch pipe, and at one joint, misalignment was observed (Photos 26, 27, 29).

The diversion structure outlet consists of an 8-inch thick concrete headwall. The construction plans indicate the bottom of the channel at the outlet to be flush with the conduit invert. There is now a large scour hole approximately 5 feet deep in the stilling area due to erosion (Photo 22). Below the outlet of the right (east) conduit, erosion has progressed to a point below the headwall base (Photos 22 and 23). If erosion continues, it could cause undercutting of the headwall base and sloughing of the diversion structure outlet channel walls.

High discharges through the diversion structure, in its present condition, might endanger the dam embankment.

Background data for diversion structure capacity was obtained from the SCS "work plan" file (Ref. 1). Their computations were based on 36-inch diameter pipes and consequently are not representative of as-built conditions. Therefore, it was necessary to develop new hydraulic rating information. In order to estimate the diversion structure capacity, it was necessary to calculate the capacity of the box inlet and the twin pipes. The capacity of the box inlet was determined using the weir head-discharge formula with a discharge coefficient of 3.1. It is assumed the stoplogs would not be in place in the box inlet. The capacity of the pipes was calculated using the energy equation and assuming the gates are fully open, full pipe flow exists and a Manning's "n" of 0.013. Capacity to the principal spillway crest (elevation 2856.65 feet NGVD with stoplogs) is estimated to be approximately 67 cfs, and 424 cfs to the design dam crest control elevation (2863.0 feet NGVD). Complete rating data is provided in Exhibits E3 and E4 of Appendix E.

2.1.3 Freeboard

Flood routing indicates the dam overtops during the PMF. Therefore, there is no freeboard with the recommended spillway design flood. At the time of the field inspection, the reservoir water surface elevation was approximately 2852.0 feet NGVD, or 10.75 feet below the first overtopping dam crest elevation (2862.75 feet NGVD, see note on page ix). The vertical distance from the normal water surface elevation (2855.5 feet NGVD) to the first overtopping dam crest elevation is 7.25 feet. The historical highwater level is estimated to be elevation 2856.5 feet NGVD, which has an associated vertical distance of 6.25 feet to the first overtopping dam crest elevation. This highwater level was estimated by project representatives and is associated with 1978 runoff. Debris and erosion lines along the upstream face provided field evidence of historic highwater levels.

The minimum design freeboard for South Sandstone Creek Dam was not available in the SCS "work plan" file (Ref. 1). South Sandstone Creek Reservoir is basically oriented in a north-south direction, with the dam on the north end. The prevailing winds for this region are generally not aligned with the reservoir. During the winter months, the prevailing winds are northwesterly. Southeast winds prevail in the months of May thru August. The reservoir location and orientation can be observed in Appendices A and B. If the winds unexpectedly prevailed from a southerly direction, the effective fetch length would be less than 1 mile and a minimum freeboard allowance of 3.0 feet would be required (Ref 6). Although the dam will overtop during the PMF and lesser floods, the vertical distance between the normal pool level and first overtopping dam crest elevation is sufficient to prevent overtopping the dam embankment by wind-generated waves.

2.2 HYDROLOGY

2.2.1 Physiography and Climatology

The 48-square mile catchment area above South Sandstone Creek Reservoir is basically rectangular in shape, with the length dimension approximately twice the width. In particular, the drainage area is approximately 10.0 miles long and 5.0 miles wide. The terrain is generally flat and interspersed with numerous small coulees and breaks. The immediate vicinity of the reservoir can primarily be characterized as plains topography. The watershed rises from the reservoir in a southeasterly direction by gradual slopes and bench lands to the higher elevations at the divide near Willard, Montana (Photos 1-7 of Appendix C).

Soils in the watershed have parent materials commonly consisting of the sedimentary rocks such as sandstone, shale, and related rocks. The parent material was eroded, transported, and deposited at their present site by various processes. As indicated above, the watershed is described as being gently sloping to rolling sedimentary plains. These areas are dominated by undulating to rolling, well drained, dark colored loams and light colored, calcareous silt loams, underlain by silt loam sedimentary beds. A small portion of the watershed is comprised of steep to very steep silt loams, clay loams and silty clay loams underlain by silt loam, clay loam and silty clay loam sedimentary beds that outcrop in numerous severely eroded areas (Ref. 7).

The regional climate is classified as distinctly continental, with cold, dry winters and warm summers. Orographic effects on climate are relatively small. Regional variations in temperature and rainfall are not large, particularly when

compared to the extreme variable pattern common to the more mountainous western sections of Montana. In general, the majority of the annual precipitation falls during the growing season of April through September. Snowfall in the watershed is generally light and does not tend to remain on the ground for long periods of time. It is not uncommon for the region to experience winter warming spells with associated thawing temperatures (Ref. 7-10).

Annual precipitation in the region averages about 12 to 14 inches. At Plevna, Montana, which is located approximately 5.5 miles north-northwest of the dam, annual precipitation averages about 13.4 inches. The average annual temperature at Plevna is approximately 43°F. Winters are typically cold, with January being the coldest month. The monthly average temperature for January at the Plevna climatological station is about 14.5°F. During the summer, July is typically the warmest month with the average temperature in the neighborhood of 70°F (Ref. 7, 8, and 10).

Streamflow measurements are not available on South Fork Sandstone Creek and Coon Creek. Short-period records are available on some of the small regional streams. In general, those streams characterized by mountain and/or foothill drainages have either a single peak period in the late spring, or two peak periods: one in the early spring due to the prairie contributions, and one in late spring-early summer resulting from snowmelt runoff. Regional streams comprised primarily of prairie drainages exhibit either early spring peaks, or summer peaks due to quick-response runoff from thunderstorm activity (Ref. 11).

2.2.2 Estimated Probable Maximum Flood (PMF)

The inspection guidelines recommend that for a project of this type, the spillway design flood be the probable maximum flood (PMF). The PMF is defined as a flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the study region. The probable maximum precipitation (PMP) and the estimated PMF were developed for the drainage basin.

South Sandstone Creek Reservoir is located east of the 105th meridian, hence PMP values were calculated using procedures contained in the National Weather Service's Hydrometeorological Report No. 51 (Ref. 12). HMR-51 provided PMP values for durations to 72 hours. The PMP 6-hour, 24-hour, and 72-hour values are 17.1 inches, 22.9 inches, and 25.5 inches, respectively. The 6-hour increments for the total 72-hour storm were arranged in a critical distribution using criteria presented in the National Weather Service's Hydrometeorological Report

No. 43 (Ref. 13). In particular, the 6-hour rainfall increments were arranged according to pattern "e". Further subdivision of the calculated rainfall increments was required to provide compatibility with the duration of the unit hydrograph. A 30-minute unit hydrograph was selected for South Sandstone Creek Reservoir using criteria presented in the SCS Hydrology Handbook (Ref. 14). The PMP storm was plotted in the form of a depth-duration curve for convenience in selecting incremental rainfall values. The 30-minute PMP values within the peak 6-hour rainfall increment were ordered according to the reverse pattern of the largest 12 unit hydrograph ordinates.

Rainfall losses were assumed equal to zero due to assumed ground conditions. Hence, excess rainfall was assumed equal to the rainfall amounts.

The runoff condition, or PMF, resulting from a PMP storm was estimated using the PMP values and the unit hydrograph approach. A 30-minute unit hydrograph was developed for the South Sandstone basin using the U.S. Army Corps of Engineers' computer program HEC-1, and the SCS method (Ref. 15). The resultant PMF has a total runoff volume of 65,000 AF.

2.2.3 Flood Routing

The PMF resulting from the PMP rainfall/runoff event was routed through South Sandstone Creek Reservoir using the computer program HEC-1 (Ref. 15). Runoff from an antecedent storm was not specifically considered; however, it appears reasonable to assume the initial reservoir level prior to routing to PMF is at the principal spillway crest (elevation 2856.65 feet NGVD with stoplogs). The support rationale for this assumption is that South Sandstone Creek Reservoir characteristically has a small reservoir pool and is not capable of totally absorbing rather severe flood events. A partial reservoir pool drawdown can be accomplished within a relatively short period of time using the twin 48-inch diversion conduits. However, drawdown can only be achieved to elevation 2855.5 feet NGVD without the aid of pumping. It is not likely that the pool would be intentionally lowered below elevation 2855.5 feet NGVD unless it was on an emergency basis or the operators anticipated extremely high runoff from the basin. The water users would prefer to store as much water as possible in preparation for the irrigation season. In summary, the "sense of emergency" is not likely to be realized by the project operators to the extent storage water and downstream conditions would be sacrificed in anticipation of a PMF event.

Reservoir capacity-elevation data was obtained from the SCS "work plan" file (Ref. 1), and is provided in Exhibit E1 of Appendix E. South Sandstone discharge rating data is provided in Exhibits E3 and E4.

Flood routing showed that the dam would first overtop when approximately 8 percent of the PMF volume enters the reservoir. However, the valley upstream of the dam is very wide and there is considerable opportunity for natural storage along the stream channel which would reduce the magnitude of the PMF at the reservoir. Therefore, the dam would likely overtop during the PMF when more than 8 percent of the PMF volume enters the reservoir, but we believe the project cannot handle ½ PMF. The SCS designed the project for a little more than a 100-year flood, which is considerably smaller than ½ PMF. The detailed studies required to accurately analyze this drainage basin are beyond the scope of work for this Phase I study and should be addressed in future work.

Since the PMF used for this study is estimated, and not suitable for design, detailed hydrologic studies are needed prior to making project modifications.

2.3 GEOTECHNICAL EVALUATION

The geotechnical evaluation of South Sandstone Creek Dam included a field investigation and a search and review of project design data. The field inspection consisted of photo documentation, a dam crest profile survey, slope stability observations of the dam embankment, and measurements of the slope angles. Inspection photos are included in Appendix C, some construction drawings are provided in Exhibit D1 of Appendix D, the crest profile survey is shown in Exhibit D2, results of the slope angle measurements are provided in Exhibit D3, soils design data is provided in Exhibit D4, and structural backfill instability at the principal spillway walls is described in Exhibit D5.

2.3.1 Dam Embankment

South Sandstone Creek Dam is a compacted, zoned, earth fill structure which was completed in 1975. The dam has a maximum structural height above the deepest point on the foundation surface of 47 feet and a total crest length of 2908 feet. There is a 280 foot wide emergency spillway located on the right abutment. This spillway has small, 12-foot wide (crest), dikes on each side to channel emergency flows (Sheet d of Exhibit D1). A county road passes over a portion of the main embankment. The main embankment has a crest width of 30 feet where the county road passes over it; all other sections are 15 feet wide at the crest (Sheet c of Exhibit D1).

The construction plans indicate the upstream face of the dam was designed with a slope of 1V on 2¼H down to elevation 2860.0 feet NGVD (see note on page ix). Then the slope flattens to 1V on 4H until reaching elevation 2849.0 feet NGVD. Downslope from elevation 2849.0 feet NGVD, the embankment was designed at a steeper slope of 1V on 3H. It appears that topsoil has been placed on the upstream face at elevation 2860.0 feet NGVD to protect the upper surface of the riprap and its bedding material. It should be noted that this topsoil is not shown on the construction drawings (Sheet c of Exhibit D1).

The downstream face was designed with a slope of 1V on 2.5H. Field measurements of the slope averaged about 21 degrees which approximately verifies the design. There is a moderate to dense cover of natural grasses and weeds on the downstream slope (Photos 11 and 22).

Sheet c of Exhibit D1 of Appendix D indicates the embankment cross section consists of three parts: Zone I, an impervious material; Zone II, a pervious material; and Zone III, the riprap section. Zone I material is described as sandy and silty clays and Zone II is sands and silty sands. Zone III, riprap, is described as gravel with a maximum rock size of nine (9) inches and of the material passing the 3 inch sieve, not more than fifty (50) percent passing the one inch sieve and not more than five (5) percent passing the No. 200 sieve.

The impervious section, Zone I, is located in the central and upstream region of the embankment. There is a cutoff trench located at the base of the impervious section. Construction drawings indicate that the cutoff trench extends into the underlying bedrock throughout the entire length of the dam (Sheet a of Exhibit D1, Appendix D).

The Zone II material consists of bedding for the riprap zone and drainage material at the downstream toe. Along a portion of the main embankment, from construction drawing stations 11+80 to 21+80, where the crest width is 30 feet, the embankment has apparently been thickened using this Zone II material.

2.3.2 Foundation Conditions and Seepage Control

There were 42 test holes made in the area of embankment at the time of design. In addition, 12 test holes were made in the borrow areas. Laboratory testing included Atterberg Limits, grain size distribution, moisture-density relationships, and specific gravity tests. Strength, consolidation, and permeability tests apparently were not performed.

Based on the construction drawings and the available information, it appears that the existing main embankment is resting primarily on deposits of sand and gravel, and some clay. In the dike area, the foundation material is predominately clay. The cutoff trench described earlier was designed to extend through the permeable materials and into the shale bedrock.

Shale bedrock underlies the clay, sand, and gravel at depths of approximately 5 to 20 feet. This material is described in the early geology correspondence as being impermeable (Ref. 1).

Settlements

The construction plans indicate that the design dam crest control elevation was established at 2863.0 feet NGVD, and a camber up to 1 foot thick was added to this elevation. An embankment profile was surveyed on October 16, 1979 (Exhibit D2 of Appendix D). The survey shows that points on the crest vary from slightly below to slightly above the control elevation. The crest in the area of the main embankment averages about 2863.5 feet NGVD which suggests that the average settlements in this area have been approximately 6 inches with maximum settlements of about one foot. Differential elevations along the embankment are relatively minor. These consistent elevations may be the result of regular grading of the road along the crest.

Misalignment along the diversion structure conduit appears to be in the range of 3 to 5 inches. The joints along this conduit have separations of 2 to 3½ inches. This misalignment and joint separation suggest that significant settlements have occurred since placement of the conduit. The amount of settlement in this area could not be determined accurately at the time of investigation.

Settlements have occurred at the principal spillway. Local employees with the Soil Conservation Service say that settlements in this area have been in the range of 0.2 to 0.4 of a foot. Some distress resulting from these settlements is evident. The portion of the chute supporting the bridge has apparently settled more than the adjacent chute control sections because the bridge abutments are stressing the chute walls. The chute walls are cracking as a result of this loading (Photo 17).

Due to settlement of the principal spillway, the chute length is shortening slightly, forcing out the joint material (Photo 14).

In summary, a history of settlements along the dam embankment is lacking; however, there are obvious indications that significant settlements have occurred. These settlements have caused some structural damage in the principal spillway and diversion outlet structure.

Seepage Control

At the time of the September 1979 field investigation, the South Sandstone Creek Reservoir pool was at an approximate elevation of 2852.0 feet NGVD. Springs were identified near the bottom of the natural downstream channel and in the stilling basin of the principal spillway. No seepage areas positively relating to dam underseepage were identified. Underseepage is not considered a problem. However, some downstream seepage areas may appear during periods of high pool.

2.3.3. Stability

Embankment

The slope angles measured during the field investigation are shown in Exhibit D3 of Appendix D. These angles were measured with an Abney hand level and should be considered approximate.

A slope stability analysis was performed by the SCS. A coefficient of horizontal acceleration of 0.1g was used to determine the seismic loading effects on the structure. A summary of the resultant factors of safety are as follows:

Factor of Safety	Slope	Loading Condition
1.248	Upstream	Complete drawdown
1.070	Downstream	Complete drawdown with seismic loading
1.170	Downstream	Dry slope, insignificant surface slumping
1.466	Downstream	Moist slope
1.250	Downstream	Moist slope with seismic loading

A phreatic surface through the embankment was assumed and is approximately represented (HKM interpretation of SCS data) on Sheet c of Exhibit D1 of Appendix D. There are no piezometers in the embankment and the actual internal seepage conditions are unknown.

Conventional soil strength tests were not performed. Soil design parameters were apparently estimated by relating project soils with soils of known strength having similar physical characteristics. The soil parameters used in the stability analysis are listed in Exhibit D4.

There is no outward stability or seepage problems evident from visual inspection of the dam embankment. The calculated stability factors of safety appear to conform to the Recommended Guidelines. However, because the strength data was not obtained by laboratory testing of the embankment and foundation soils, and because the piezometric conditions are unknown, there is insufficient information for evaluation of the embankment stability.

Principal Spillway

There are chute stability problems evident from visual inspection of the principal spillway. As discussed previously, settlements have occurred in the embankment and/or foundation in this area, causing deformation of the concrete spillway structure. All of the six drain pipes exiting into the upper end of the chute have experienced some shear as a result of the combined movements of the soil backfill behind the chute walls and settlements. The locations of these drain exits are shown in Sheet e of Exhibit D1 of Appendix D. Large voids are visible behind the chute walls (Photo 19). These voids are the result of erosion from water moving through poorly compacted backfill material. A sketch representing these conditions is shown in Exhibit D5. As a result of the backfill settling adjacent to the chute wall, tension cracks have developed, running parallel to the chute (Photo 18) and surface runoff is concentrating along the walls. In conclusion, stability of the chute is a problem. There is a danger that a rapid failure of the spillway could occur if, during a period of high spillway flow, water entered the backfill through the drain exit holes and ran down the slope, behind the walls.

Erosion and Riprap

Bank erosion was observed at several locations. On the upstream face of the dam, waves have run up the slope during periods of high pool and have cut the topsoil overlying the riprap to a near vertical configuration (Photos 32 and 33). Although these vertical cuts are low, approximately 1 to 3 feet, local sloughing is occurring and disfiguring the embankment. This erosion is not presently causing a serious problem, however.

Bank erosion is evident in the stilling basin area of the principal spillway (Photo 20). During periods of high flow, the churning action of the water in the stilling basin is cutting the banks. This situation does not pose any immediate problems, eventually however, the disconfiguration of the basin may become unreasonably large. Riprap should be placed around the entire stilling basin to at least the maximum water elevation.

The stilling basin immediately below the diversion structure outlet is scoured badly. The bottom of the basin has been eroded to the point that the endwall of the outlet has been undercut. Presently, there is no riprap in this area.

Some minor erosion is evident on the upstream side of the abutment contact. This erosion is the result of surface runoff water from the west. This erosion does not pose an immediate danger.

Slope protection on the upstream face of the dam is inadequate. The present protection is a gravel blanket with occasional sandstone cobbles and boulders, and it extends up to about elevation 2860.0 feet NGVD. A description of the original slope protection placed on this face could not be found in the "work plan" file, but it is expected that the original material was somewhat coarser than the present material. The average size of this material appears to be about 3 inches, and the gravel is subrounded. Because of the small size and smooth texture of this riprap, wave runup is high and the topsoil covering the horizontal riprap surface is being undercut.

2.4 PROJECT OPERATIONS AND MAINTENANCE

2.4.1 Dam

There is no formal written plan for operation or maintenance of South Sandstone Creek Dam. Responsibility for operation and maintenance of the dam, including the spillways, is shared by the MDFWP and the SSG. The MDFWP and SSG are both responsible for the operation of the diversion structure, with the SSG having sole responsibility for its maintenance. (Ref. 1 and discussions with the project owners/operators).

The project was originally designed so that the inlet elevations for the diversion structure and principal spillway were exactly concurrent at 2855.5 feet NGVD. However, the principal spillway box inlet is approximately 0.35 of a foot low relative to the plans (Correspondence, Appendix F). To re-establish the concurrency, the project operators have installed a 4-inch stoplog as a permanent feature in the spillway notches. The operators have the option of inserting or pulling stoplogs at either the principal spillway or the diversion structure according to the time of year and water use demands (source: discussions with the project owners/ operators).

Available records, and discussions with the project owners/ operators, indicate that minimal maintenance has been required and performed since construction completion. The diversion structure and principal spillway operate annually, and evidently there has been no operational problems. The emergency spillway has never operated since its construction in 1975.

Discussions indicate that an annual inspection is performed on the dam by the MDFWP and SSG. Generally the SCS also has a representative attend the annual inspection.

2.4.2 Reservoir

Although there is no formal written plan for reservoir operation, it appears that the MDFWP and SSG have a good understanding of project operation and maintenance responsibilities. In particular, the MDFWP has responsibility for the operation and maintenance of the fish management and recreation activities. Pool levels and reservoir releases are generally dictated by seasonal requirements. Seasons of particular interest are the spring and early-summer runoff period, and the irrigation period. Releases during the irrigation season are monitored and controlled according to water rights and needs. Reservoir pool carry-over from year to year also plays a part in project operation. No operation manual for the project has been prepared, and minimal operating records are maintained for components of the storage and water delivery system. Important points to be realized in reservoir operation is that the actual controllable reservoir level is only 1.5 feet, utilizing timber stoplogs, and there is no low-level outlet facility.

Specific maintenance and repairs for the reservoir basin were not noted in the project files. According to the project owners/operators, this type of work has not been required to date. Some bank erosion was observed along the shorelines, but it was not extensive and indicative of major bank instability (Photo 34). A transect section has been surveyed in the reservoir basin for sediment monitoring, but has not yet been actively used.

2.4.3 Warning System

There is no formal warning system or plan of action to warn downstream inhabitants in the event of dam distress.

CHAPTER 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of the project in accordance with the guidelines (Ref. 2) and the contract performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification and Safety Evaluation

In accordance with inspection guidelines, South Sandstone Creek Dam is intermediate in size and, based on our visual inspection and engineering judgment, it has a high downstream hazard potential. Therefore, the guideline's recommended spillway design flood (SDF) for this project is 100 percent of the PMF. Based on reconnaissance level investigations, the project is incapable of handling a flood having one-half the PMF hydrograph ordinates without overtopping and causing the dam to fail which, in our judgment, could seriously jeopardize life and property downstream. Under the inspection criteria, South Sandstone Creek Dam is considered unsafe, nonemergency until the recommended actions are complete.

3.1.2 Spillways

The spillway system consists of a principal and emergency spillway facility, and in combination, is designed to accommodate a relatively small flood event compared to current standards. Maximum combined spillway capacity, assuming the reservoir pool is at the design crest control elevation, is approximately 5850 cfs. The floodwater storage capability from the present control elevation of the principal spillway (elevation 2855.5 feet NGVD) and the current low point on the dam crest (elevation 2862.75 feet NGVD) amounts to 1170 AF. In comparison, the PMF for the 48 square-mile drainage area is estimated to have a total runoff volume of about 65,000 AF. The combination of reservoir storage and spillway discharge capabilities is inadequate to prevent overtopping of the dam during the PMF.

The concrete-lined principal spillway is in relatively poor condition considering its short term of operation. The structure has settled, concrete cracking and spalling is evident, soil settlement has occurred in the backfill with a consequent damaging of the drain pipes, and minor sloughing is occurring in the earthen banks in the stilling basin.

The earthen emergency spillway has not been required to operate since construction, and is in excellent condition. A dense vegetative cover has been established throughout its length.

3.1.3 Diversion Structure

The diversion structure was inspected from inlet to outlet; however, the slidegates were not operated. A minor problem at the intake structure involves the accumulation of gravel and debris in the inlet. Other problems of more significance include: exposed concrete aggregate of the east conduit at the contact with the slidegate; horizontal misalignment of the west conduit; major separation of joints and a lack of joint sealant in both conduits; differential settlement along the conduit lengths; and severe scouring at the outlet. There is no record or evidence of corrective measures being performed since construction.

3.1.4 Dam

South Sandstone Creek Dam appears to be stable and in good condition with no significant seepage or stability problems evident. Some problems exist with respect to the stability of the principal spillway chute walls. Substantial cracking and settlement of the backfill has occurred, with resultant damage to the local drain system and diminished support for the concrete walls. Because of the broken drains and eroded backfill, serious damage to the spillway and adjacent embankment may occur during large spillway flows.

No piezometers have been installed in the dam. A slope stability analysis was conducted during the design using assumed soil shear strengths. The calculated factors of safety conform to the Recommended Guidelines. However, because the strength data was not obtained by laboratory testing of the existing embankment, and because the piezometric conditions are unknown, there is insufficient information for the evaluation of embankment stability.

There is no low-level outlet to allow complete draining of the pool. Originally the project was designed with a minimum outflow elevation at 2855.5 feet NGVD, which was shared by the diversion structure and principal spillway with stoplogs removed. Because of the settlement in the principal spillway, the minimum outflow elevation is currently 2855.15 feet NGVD in the spillway notches. This elevation is still substantially above shallow pool levels, such as elevation 2848.2 feet NGVD which is associated with the 50-year sediment accumulation level. To obtain a more complete drawdown of the pool, pumping or an induced breach would be required.

3.1.5 Geology

The geologic investigation for this report was based on the subsurface profile drawing and soil boring logs, regional

geology reports, information contained in the SCS "work plan" file, and a surficial field investigation. South Sandstone Creek Dam is located in a generally shaly section of the Fort Union formation. The foundation in the valley floor consists of weak saturated silty sands and clays underlain by alluvial sands and gravels. No major foundation problems were noted. Some soil instability was observed in the vicinity of the principal spillway walls, and along the reservoir shorelines. The dam is located in a relatively quiet seismic area.

3.1.6 Sedimentation

Sedimentation has not been monitored since construction of South Sandstone Creek Dam. From the field investigation and from review of available records, it can be concluded that there is nothing obvious and/or significant which would indicate design deficiencies or eminent structural problems relative to sedimentation. The rate, the distribution, and the total extent of sedimentation remain unknown at this time. A transect has been surveyed in the reservoir basin to monitor sediment accumulations, but has not yet been used.

3.1.7 Operation and Maintenance

There are no formal operation plans and/or maintenance programs for South Sandstone Creek Dam. The dam is visited regularly throughout most of the year by representatives from the MDFWP and the SSG. These representatives regulate storage levels and water releases for fish management, recreation, and downstream waterspreading requirements. An annual project inspection is performed jointly by the MDFWP and SSG, with occasional representation of the SCS. No repair work of any significance has been accomplished in the past. A warning system to alert downstream inhabitants of dam distress has not been developed.

3.2 RECOMMENDATIONS

Due to storage between normal pool and dam crest, the present project provides a degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing this existing flood protection.

(1) Immediately develop, implement, and periodically test an emergency warning plan for use in the event of dam distress.

(2) Repair all concrete cracking and spalling in the principal spillway.

(3) Remove the existing structural backfill behind the principal spillway chute walls and repair the subsurface drain pipes. Provide flexible connections between the pipe in the soil material and the drain outlets in the chute walls. Backfill and grade the embankment slopes to provide positive surface drainage away from the chute walls.

(4) Repair and stabilize the eroded bank areas in the principal spillway stilling basin. Rock riprap is suggested.

(5) Major rehabilitation is required on the diversion structure. Remove the debris and gravel from the inlet. Regrade the upstream slope and place riprap around the inlet to prevent erosion and wave displacement of the adjacent embankment material when the inlet is in operation. Grout the exposed concrete aggregate area of the east conduit. Repair the joint separations and apply the required joint sealer in both conduits, and clean all deposited material from the conduit inverts. Check pipe grades from inlet to outlet and make the necessary modifications to provide positive grading to the outlet. Repair and protect the outlet from further erosion by using rock riprap.

(6) Repair the upstream embankment slope areas where wave action has cut nearly vertical slopes. Place riprap to prevent future erosion.

(7) Establish reference points along the embankment surface, on the diversion structure, and on the principal spillway, and monitor future slope movements and/or settlement.

(8) Add selected fill along the dam crest and regrade where necessary to bring the crest elevation back to the design control elevation. Particular attention should be directed to the dike section on the west side of the dam.

(9) Develop a plan for emergency draining of the reservoir.

The above recommendations will not make the project safe but will reduce involved risks while the following recommendations, with subsequent actions, are being accomplished:

(10) Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity and modify the project as studies indicate.

(11) Install piezometers for measurement of the phreatic surface in embankment, foundation and abutments. Take soil samples and perform laboratory testing as appropriate to determine soil shear strength characteristics. Compare actual piezometric conditions and soil strength characteristics to those assumed in the designer's stability analysis, and/or conduct additional analysis as needed to evaluate the embankment stability. Modify the embankment as studies indicate to assure the dam's stability is in conformance with the recommended guidelines criteria.

(12) Conduct periodic inspections by qualified engineers at least once every five years to determine whether there are any deficiencies in the condition of the project, to assess the adequacy and quality of maintenance, and to evalute methods of operation. Occasionally observe the downstream area for seepage which may occur during periods of high pool levels. Note changes in surface erosion patterns.

(13) Formalize a periodic operation and maintenance plan for the dam and appurtenant structures.

Prior to performing engineering studies and remedial construction, coordinate the work with the State of Montana, DNRC, Dam Safety Section, to insure compliance with all pertinent laws and regulations.

REFERENCES

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2. U.S. Army Corps of Engineers, Office of the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspection of Dams", Washington, D.C., Department of the Army, May 1975.

3. U.S. Geological Survey, Miles City, Montana; North Dakota, AMS, Scale 1:250,000, 1953 with limited revision 1965.

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5. Soil Conservation Service, National Engineering Handbook, Section 14, Drawing ES93, Sheets 5-7.

6. U.S. Bureau of Reclamation, Design of Small Dams, 2nd. Edition, 1973, Revised Reprint, 1974.

7. Department of Planning and Economic Development, State of Montana, "Comprehensive Area-Wide Water and Sewer Plan, 1970, State of Montana, Custer, Powder River, Fallon and Carter Counties", 1971.

8. State Engineer's Office, Water Resources Survey--Carter, Fallon, and Wibaux Counties, Montana, June 1960.

9. National Oceanic and Atmospheric Administration, Climates of the States, Volume II, "Western States Including Alaska and Hawaii", Port Washington, N.Y., 1974.

10. National Oceanic and Atmospheric Administration, Climatological Data, Montana, National Climatic Center, Asheville, N.C.

11. U.S. Geological Survey, Water Resources Data For Montana, - 1977.

12. National Weather Service, Hydrometeorological Report No. 51, Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, Washington D.C., June 1978.

13. National Weather Service, Hydrometeorological Report No. 43, Probable Maximum Precipitation, Northwest States, Washington, D.C., 1966.

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(Continued)

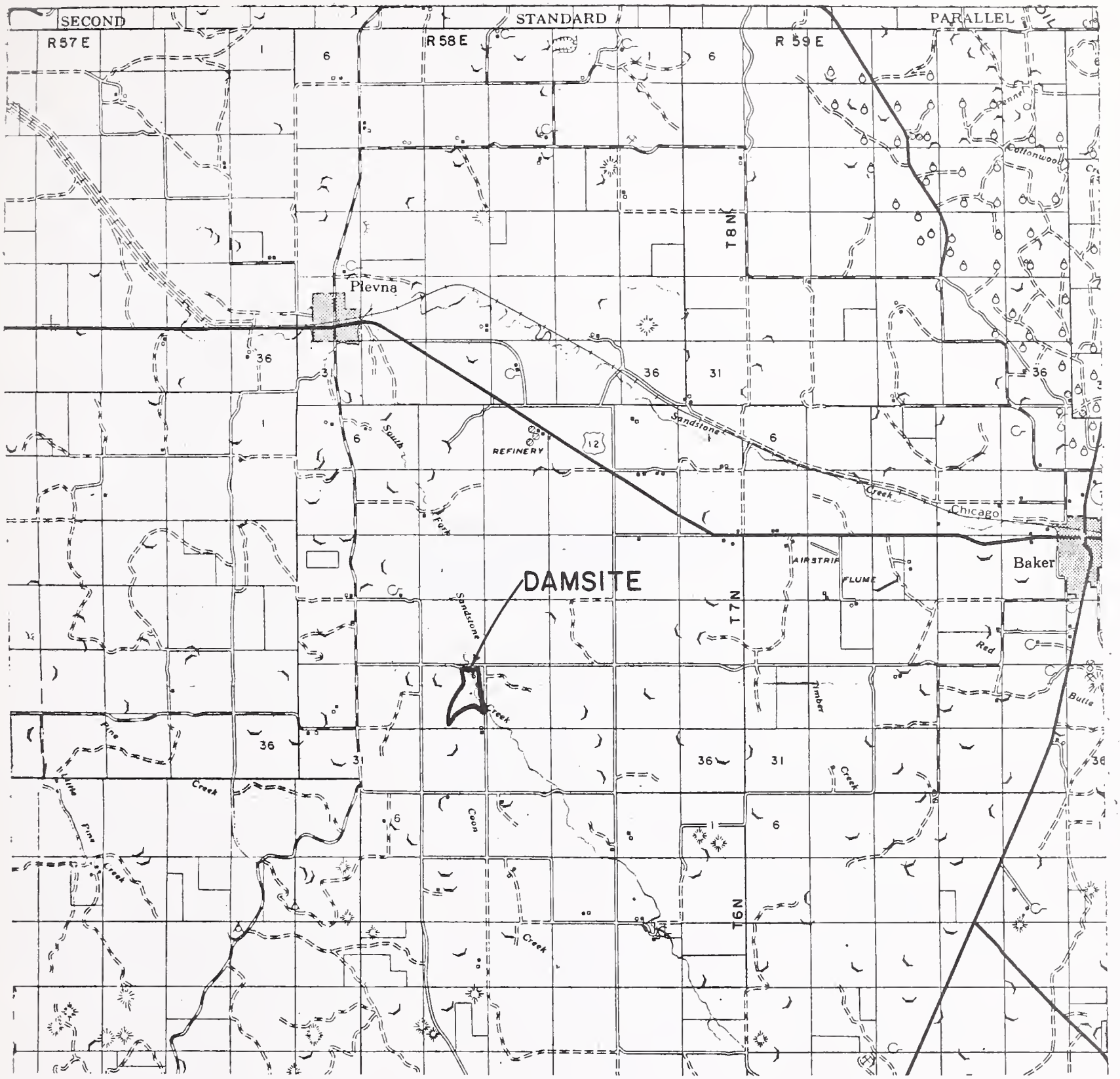
14. U.S. Soil Conservation Service, National Engineering Handbook, Section 4, "Hydrology", Washington, D.C., 1969.

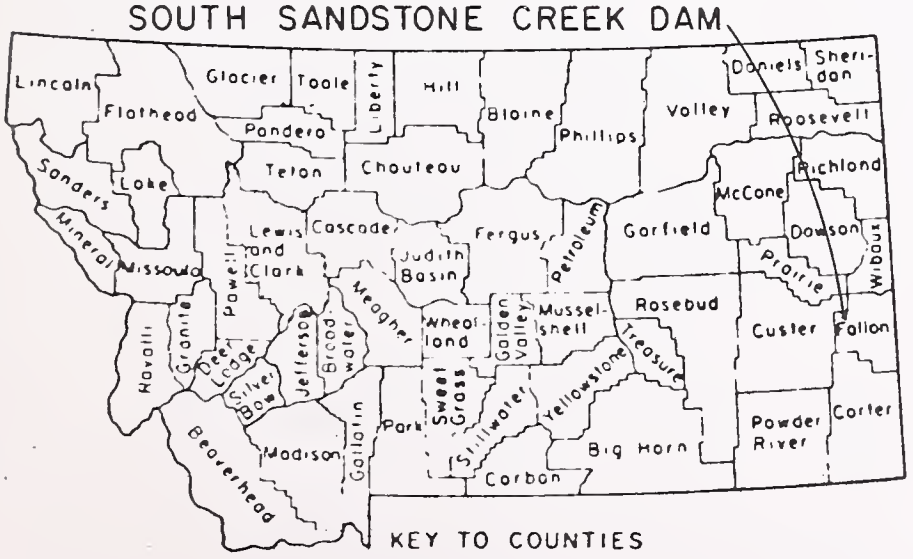
15. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Davis, California, September, 1978.

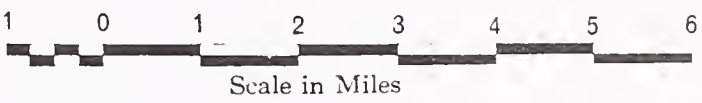
16. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-2 Water Surface Profiles, Davis, California, October, 1973.

APPENDIX A

SOUTH SANDSTONE CREEK DAM
VICINITY MAP





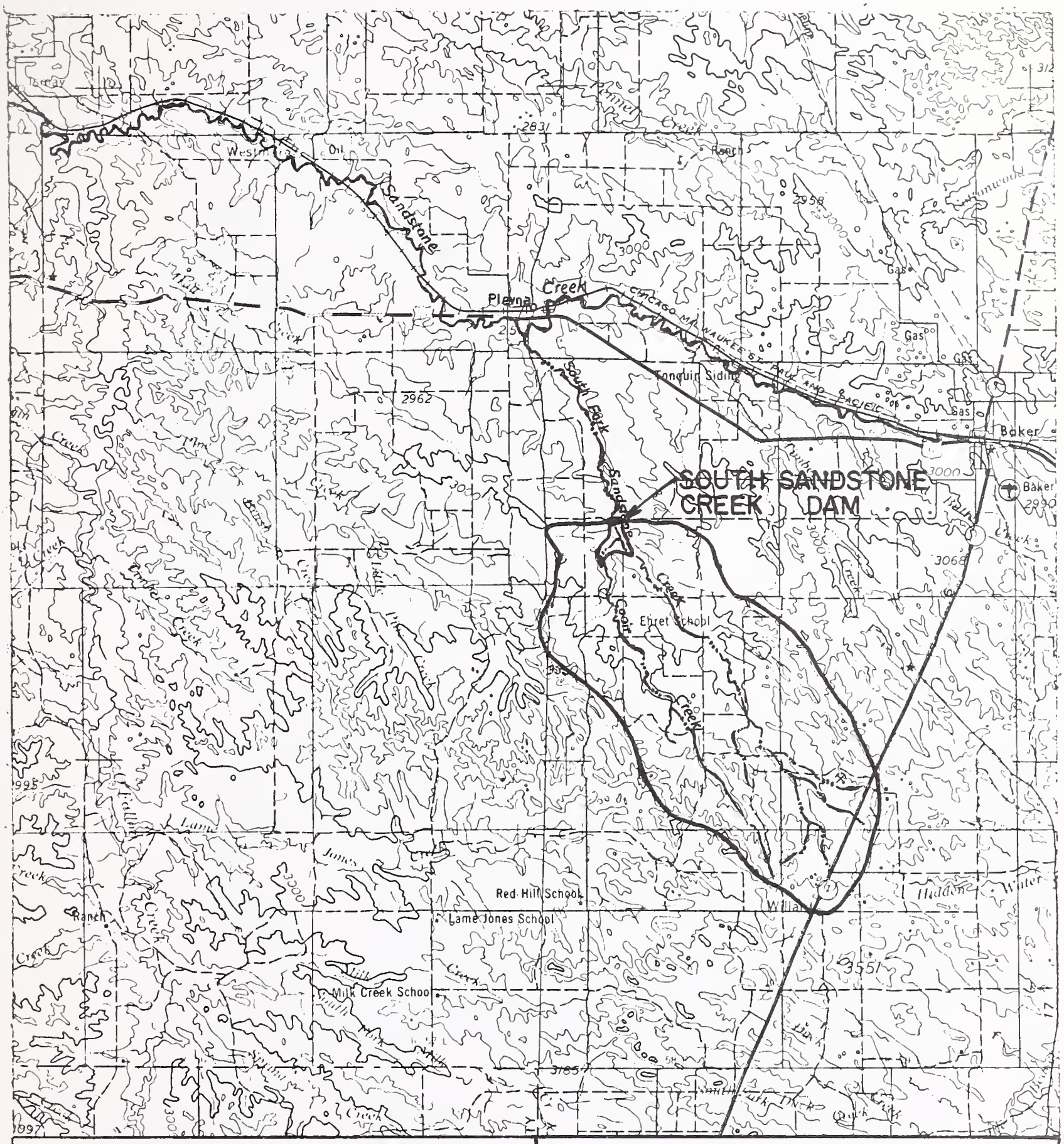


SOURCE: RESOURCE MAP, FALLON 30
BUREAU of LAND MANAGEMENT

APPENDIX A
VICINITY MAP
SOUTH SANDSTONE CREEK DAM

APPENDIX B

SOUTH SANDSTONE CREEK DAM
WATERSHED MAP



APPENDIX B
WATERSHED MAP
SOUTH SANDSTONE
CREEK DAM

APPENDIX C

SOUTH SANDSTONE CREEK DAM
INSPECTION PHOTOS

Photo No. 1 - Dam Crest and Right Abutment.
First in a 7-picture series. Looking east. Note upstream slope configuration. Principal spillway is at bridge guard rail.

Photo No. 2 - Reservoir Basin and East Shoreline.
Second in a 7-picture series. Looking southeast. There is a recreation area on the far shore.

Photo No. 3 - Reservoir Basin.
Third in a 7-picture series. Looking south. Top of gate operator for diversion structure shown in lower right corner.

Photo No. 4 - Reservoir Basin and West Shoreline.
Fourth in a 7-picture series. West recreation area shown in center of photo along shoreline.

Photo No. 5 - West Shoreline.
Fifth in a 7-picture series. Recreation area still evident.

Photo No. 6 - Left Abutment.
Sixth in a 7-picture series. Drainage course located between different vegetative covers. Cross drainage structure for recreation area access road located under dam inspector.

Photo No. 7 - Dam Crest and West Embankment Spur.
Seventh in a 7-picture series. Looking west. Embankment spur is constructed in a northwesterly direction from the county road (refer to arrow).

Photo No. 8 - Downstream Valley.
First in a 2-picture series. Looking north from the principal spillway. The water in the foreground is in the stilling basin. Plevna, Montana is in the distant background.

Photo No. 9 - Downstream Valley.
Second in a 2-picture series. Standing near the principal spillway looking north. The water in the foreground is in the principal spillway stilling basin. Notice the old meander pattern of South Sandstone Creek. Channel now used for spillway return flows.

Photo No. 10 - East Embankment Spur.
The cars in the foreground are parking on the main embankment near the principal spillway. Looking northwest along crest of spur.

Photo No. 11 - Downstream Embankment Face.
Looking east. Notice the dense vegetative cover.
The concrete in the foreground is part of the principal spillway chute.

Photo No. 12 - Principal Spillway Drop Inlet.
Notice 1 stoplog, approximately 4 inches high, has been placed in the drop inlet. Concrete is beveled. Concrete cracks are barely visible along the sills and walls.

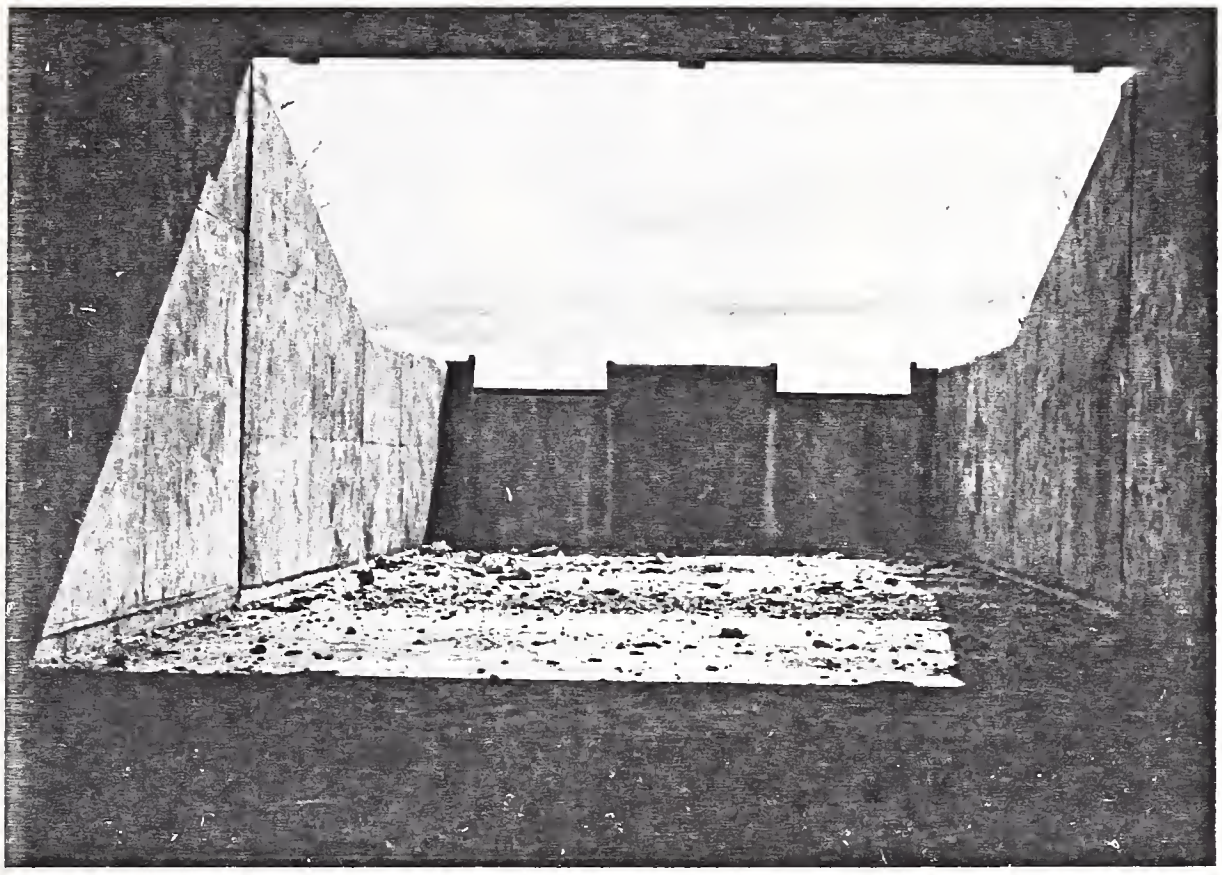


Photo No. 13 - Principal Spillway Drop Inlet.
Standing under the county road bridge looking upstream to drop inlet. The bridge is about 12 feet above the spillway floor.

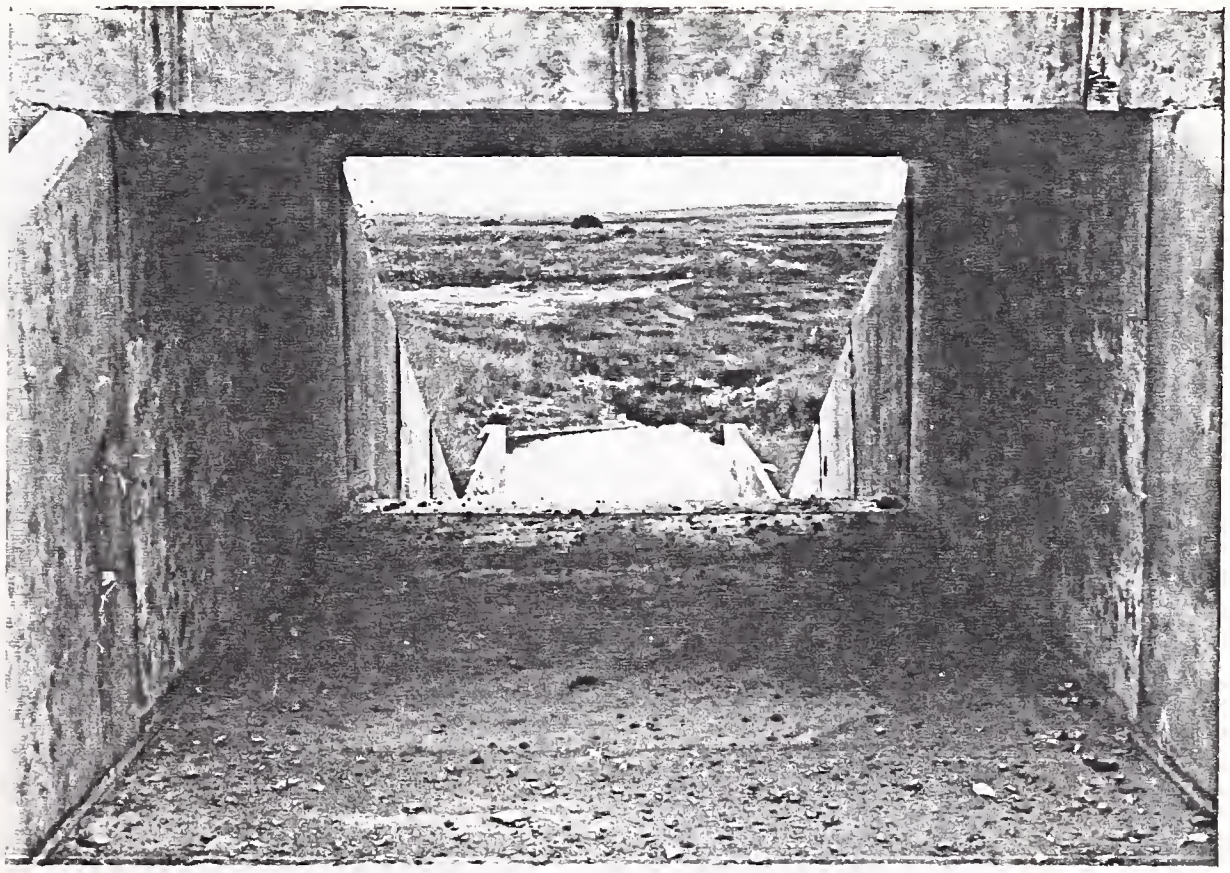


Photo No. 14 - Principal Spillway Chute.
Standing at drop inlet looking downstream. Notice joint material being forced out of vertical joints.

Photo No. 15 - Principal Spillway Drop Inlet.
The concrete is cracked on the outside edge of both drop inlets. The timber in the stoplog guides raises the inlet elevation approximately 4 inches.

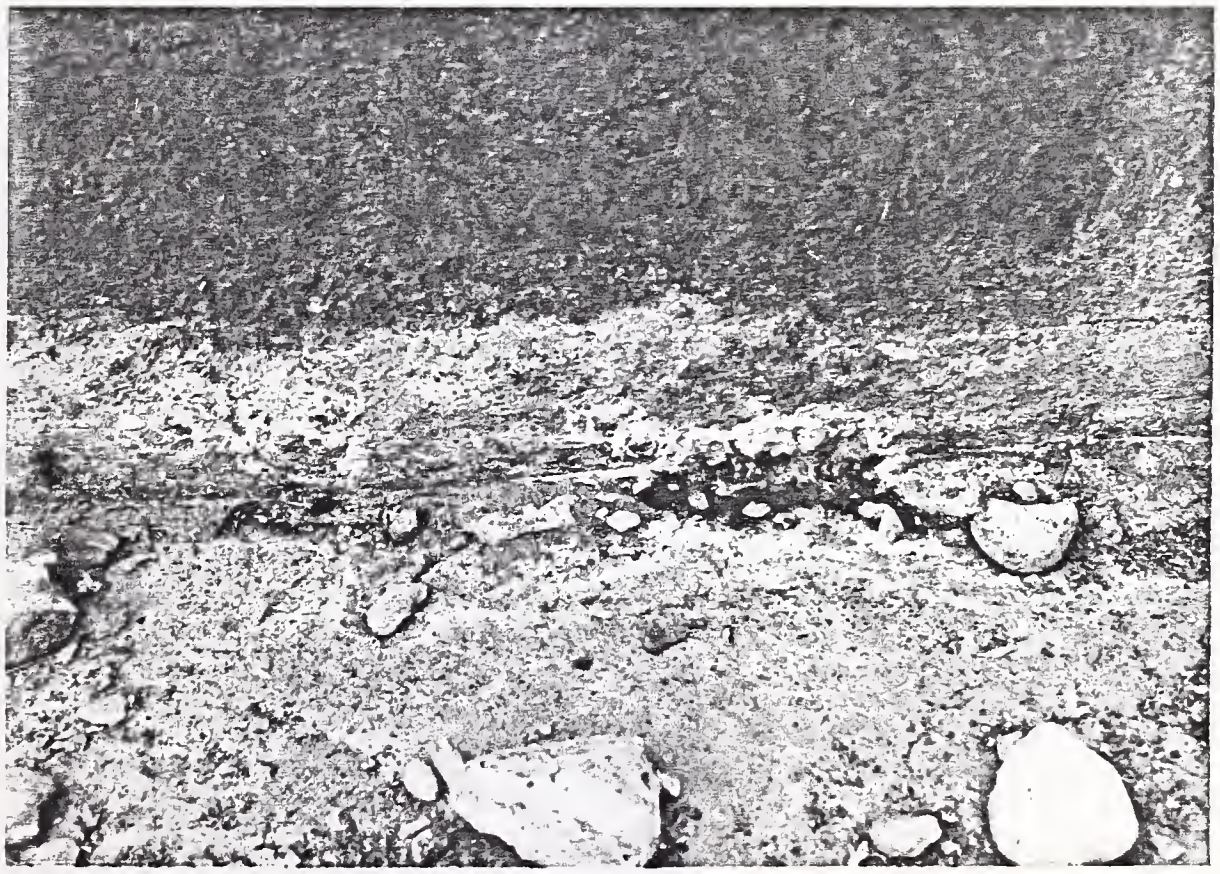


Photo No. 16 - Leak in Principal Spillway Wall.
This small leak is at the base of the drop inlet wall. Water is seeping into the spillway at the wall-to-floor joint. This leak is also visible in Photo No. 12.

Photo No. 17 - Concrete Cracking on Principal Spillway.
The horizontal concrete deck at the top of the photo is part of the bridge over the spillway. The cracking and spalling concrete is at the top of the vertical spillway wall. The concrete appears to be cracking as a result of stress concentrations from the bridge.

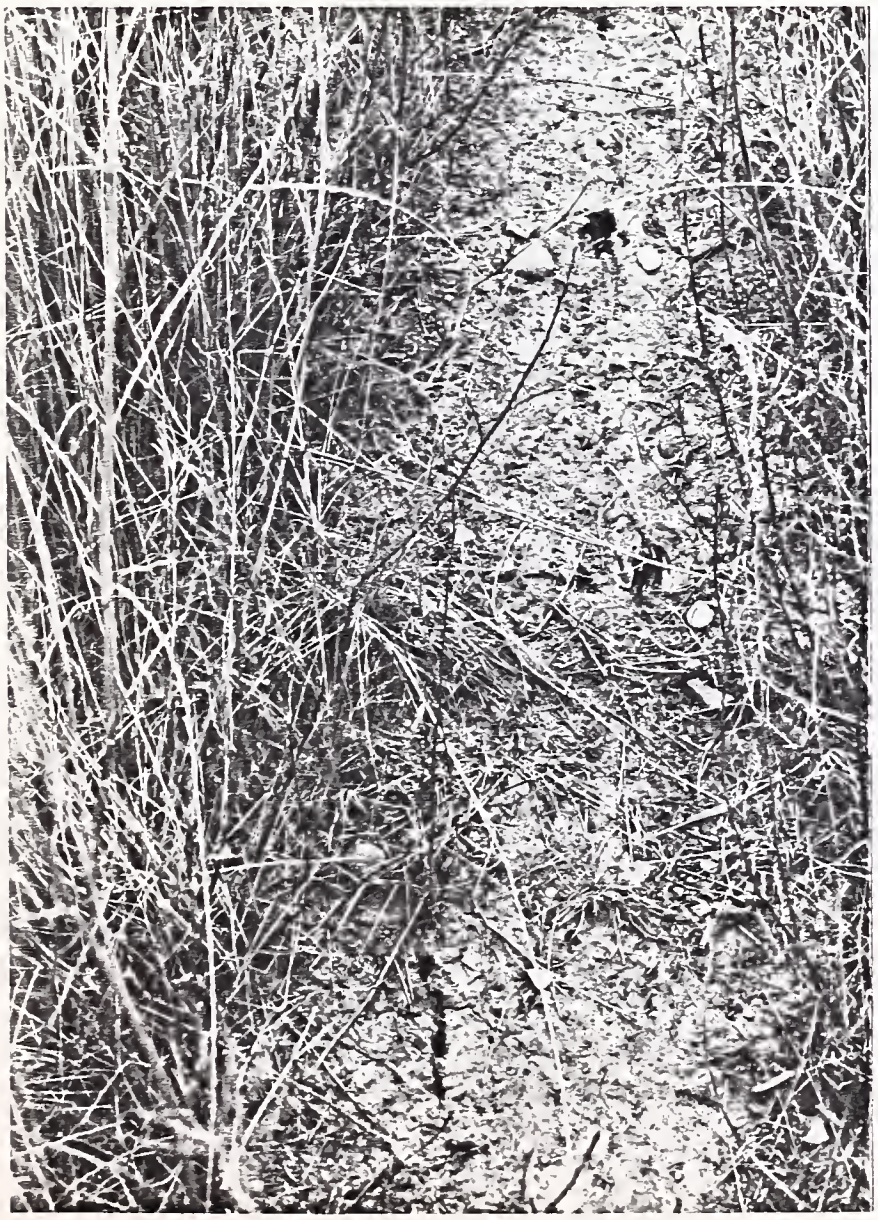


Photo No. 18 - Cracks in Backfill Around the Principal Spillway.

These cracks are the result of settlements in the backfill behind the principal spillway wall. The runoff surface is sloping toward the chute walls

Photo No. 19 - Principal Spillway Backfill.
Large holes are evident in the backfill behind the principal spillway chute walls. These holes are the result of water running behind the walls.

Photo No. 20 - Erosion in the Stilling Basin.
The vertical soil bank is the result of erosion on the west side of the stilling basin. Notice the lack of riprap protection. The concrete in the foreground is part of the spillway chute.

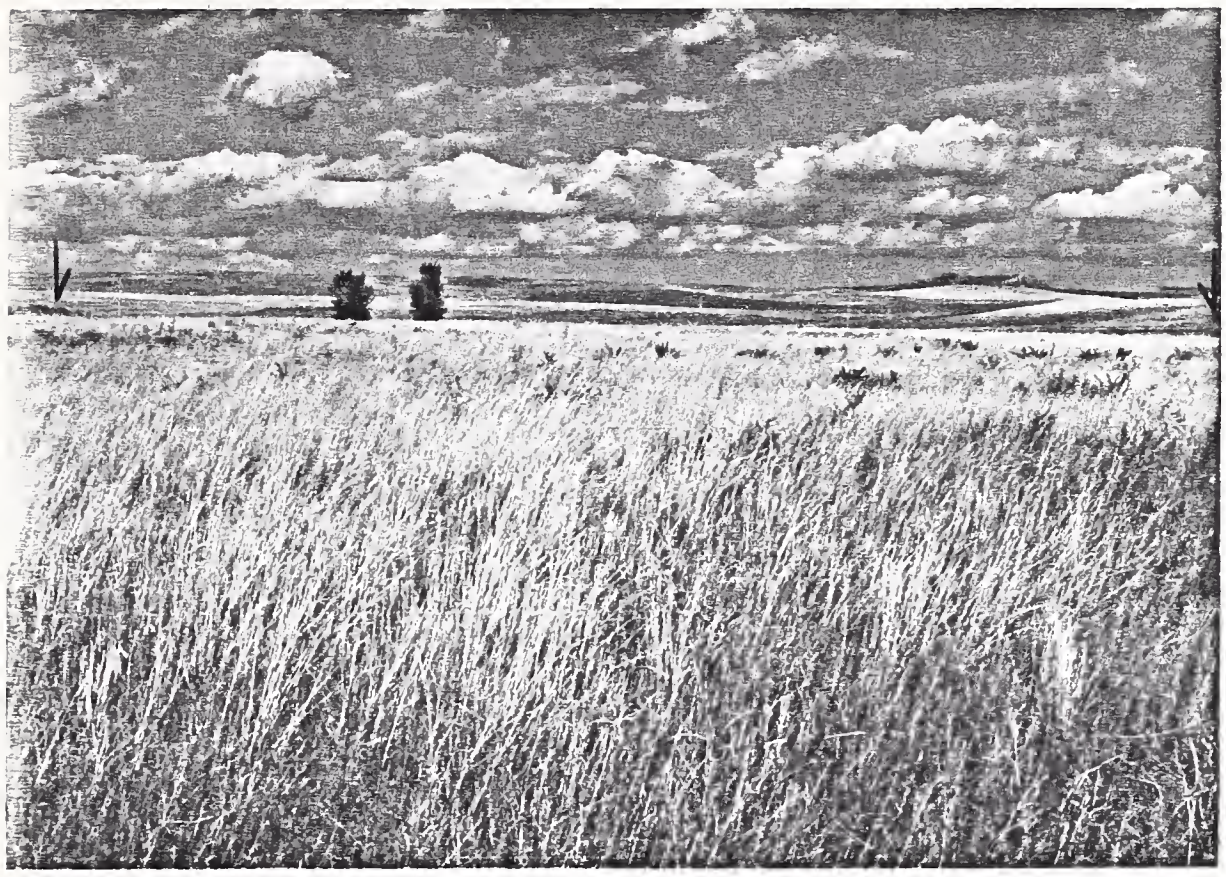


Photo No. 21 - Emergency Spillway Channel.
Looking northeast down the centerline of the emergency spillway. The banks of the spillway channel are visible at the downstream end of the control section, identified by the arrows. Notice the very dense vegetation.

Photo No. 22 - Diversion Structure Outlet.
Considerable erosion is evident in the stilling area. Notice the lack of riprap protection. Scour hole is approximately 5 feet deep. Twin 48 inch pipes are visible.

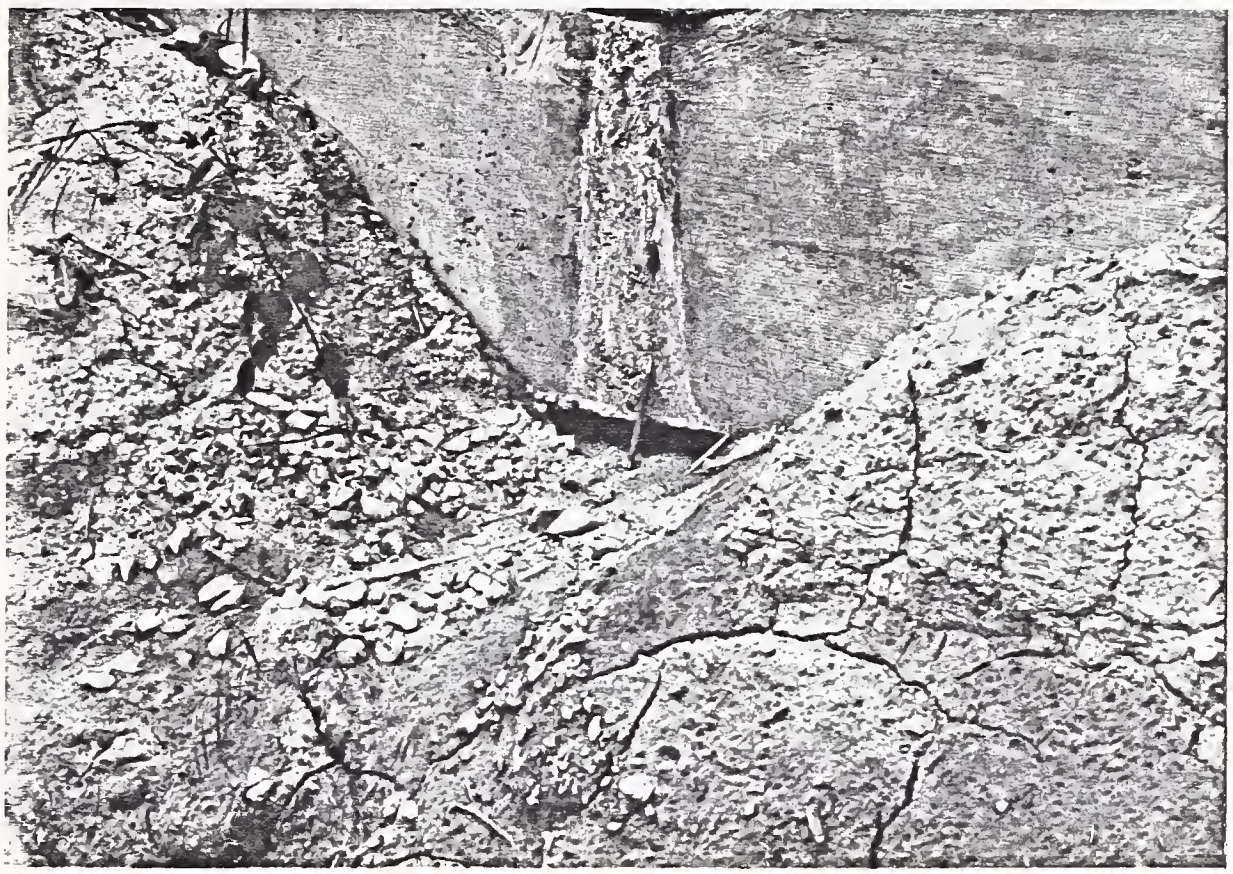


Photo No. 23 - Diversion Structure Outlet.
Note the erosion under the right (east) conduit outlet of the diversion structure.

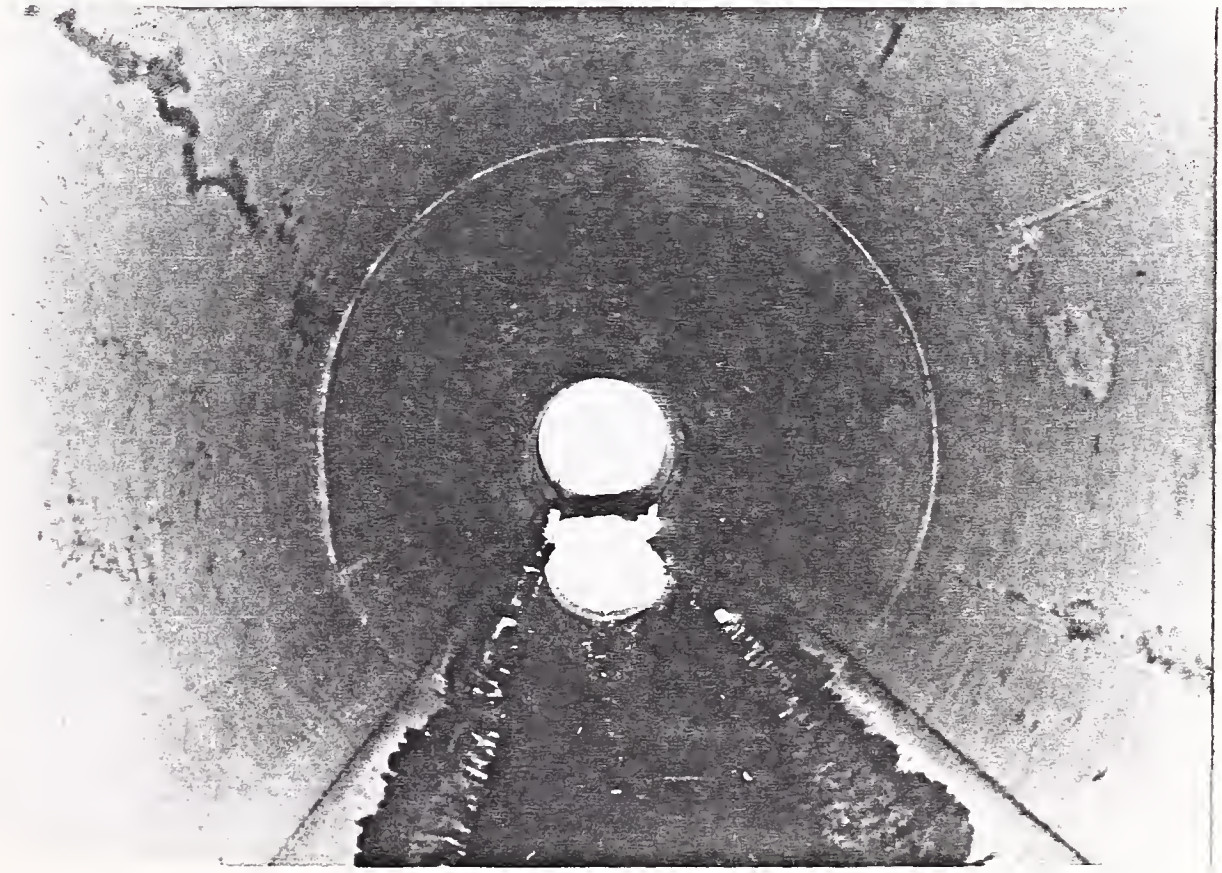


Photo No. 24 - Diversion Structure Conduit.
This is the right (east) conduit of the diversion structure. Notice the standing water which is a result of some settlement and the debris at the end of the conduit.

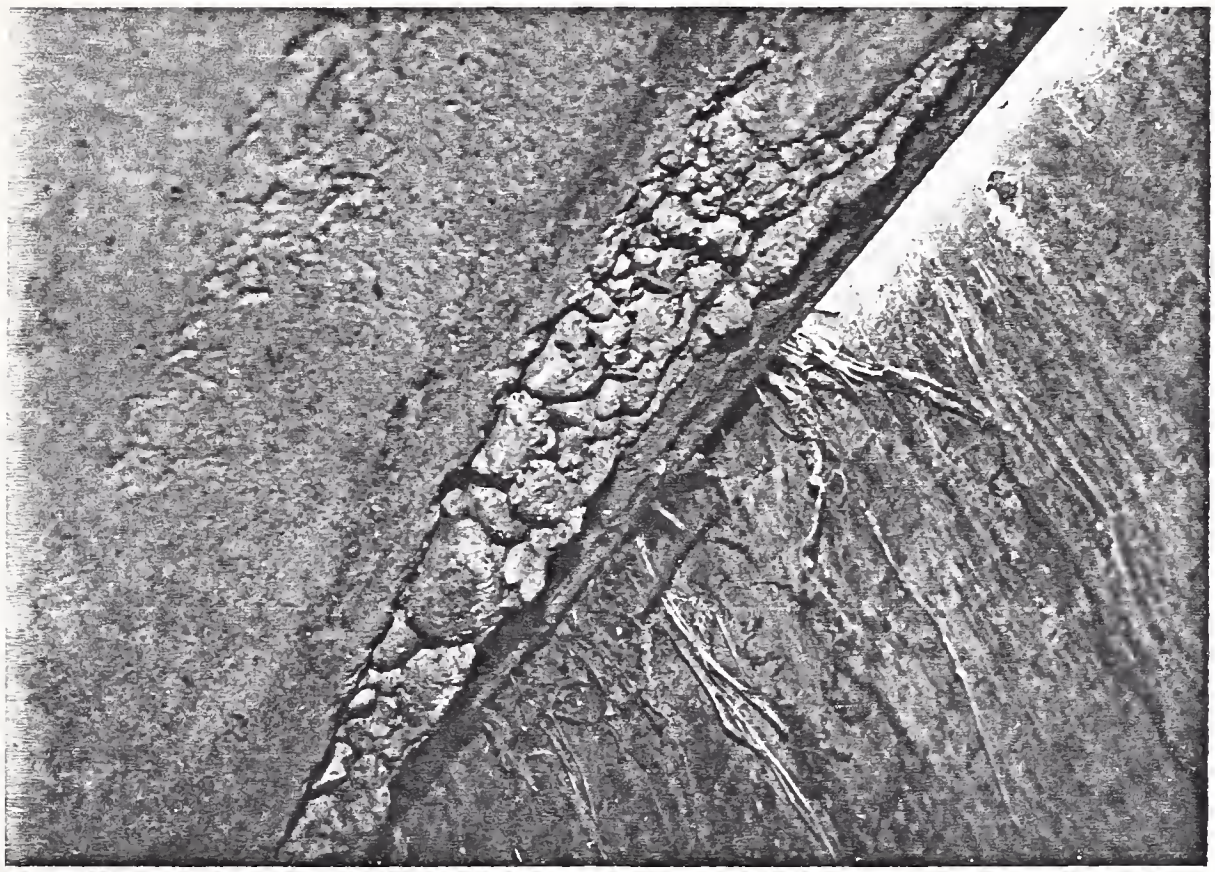


Photo No. 25 - Diversion Structure.
Picture taken of the conduit crown and slidegate contact for right (east) conduit. Notice the patching work on the exposed concrete aggregate was never completed. The slidegate is visible. The debris is wedged between the gate and the conduit.

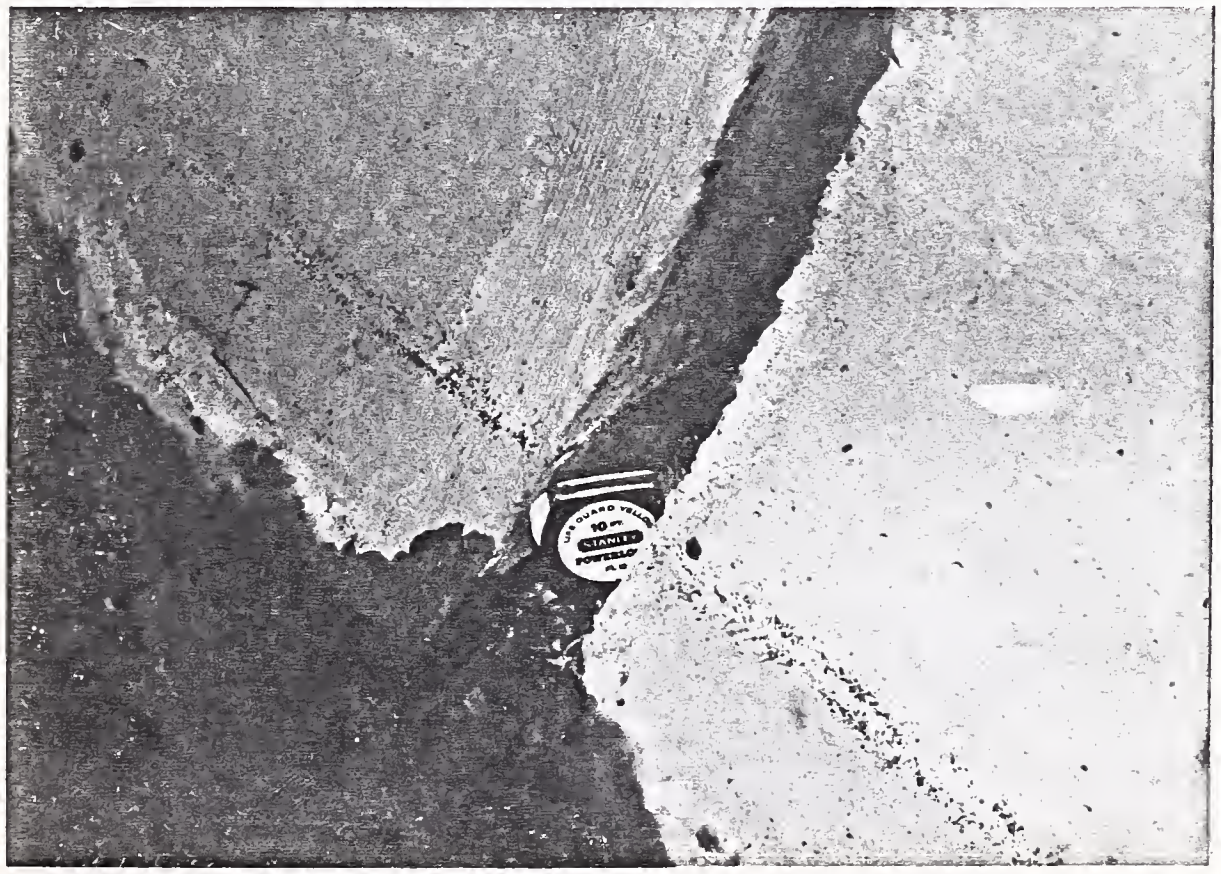


Photo No. 26 - Diversion Structure Conduit.
Joint in the right (east) diversion structure conduit is shown. There is a 2 inch gap at the joint near the downstream end of the conduit. The joint has never been grouted.

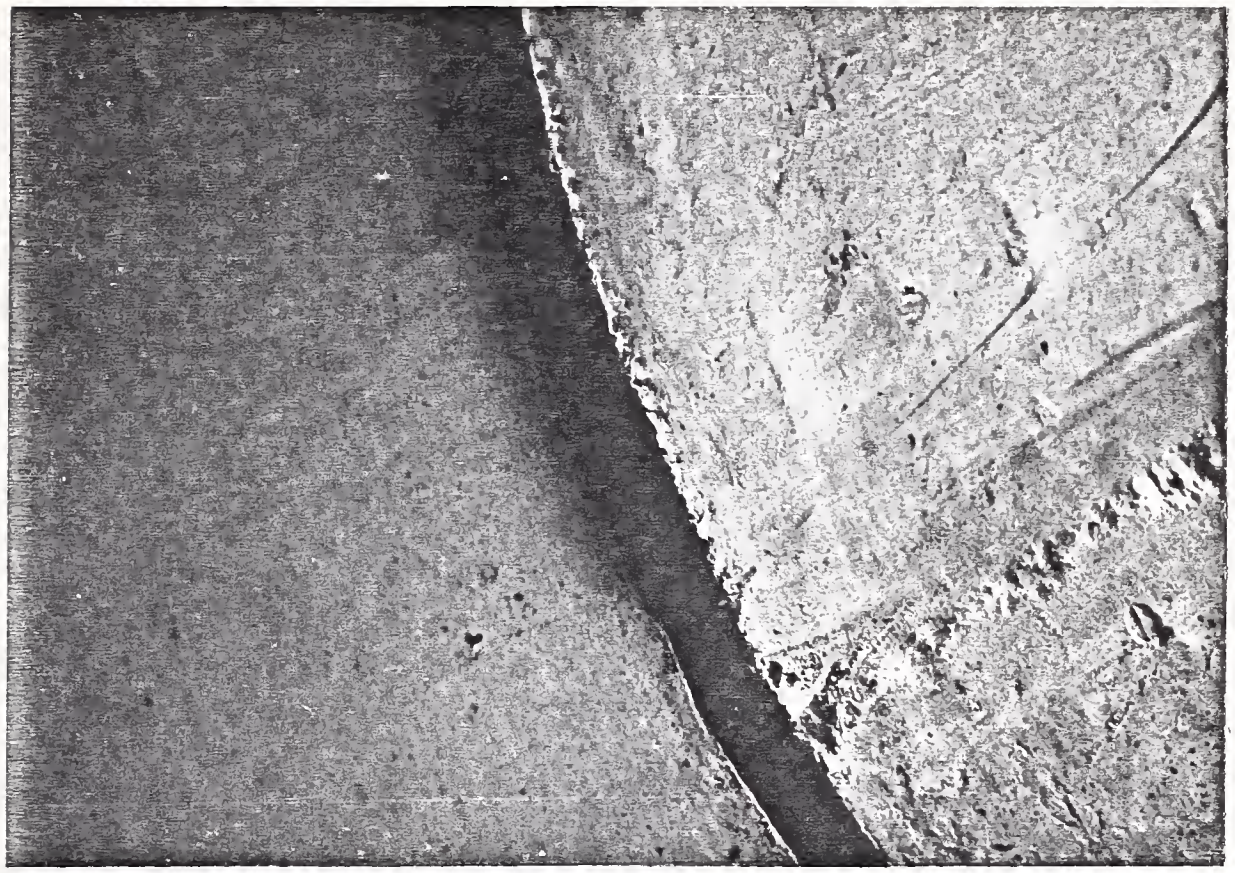


Photo No. 27 - Diversion Structure Conduit.
Joint in the right (east) diversion structure conduit is shown. This joint is slightly misaligned. Notice the joints were never grouted.

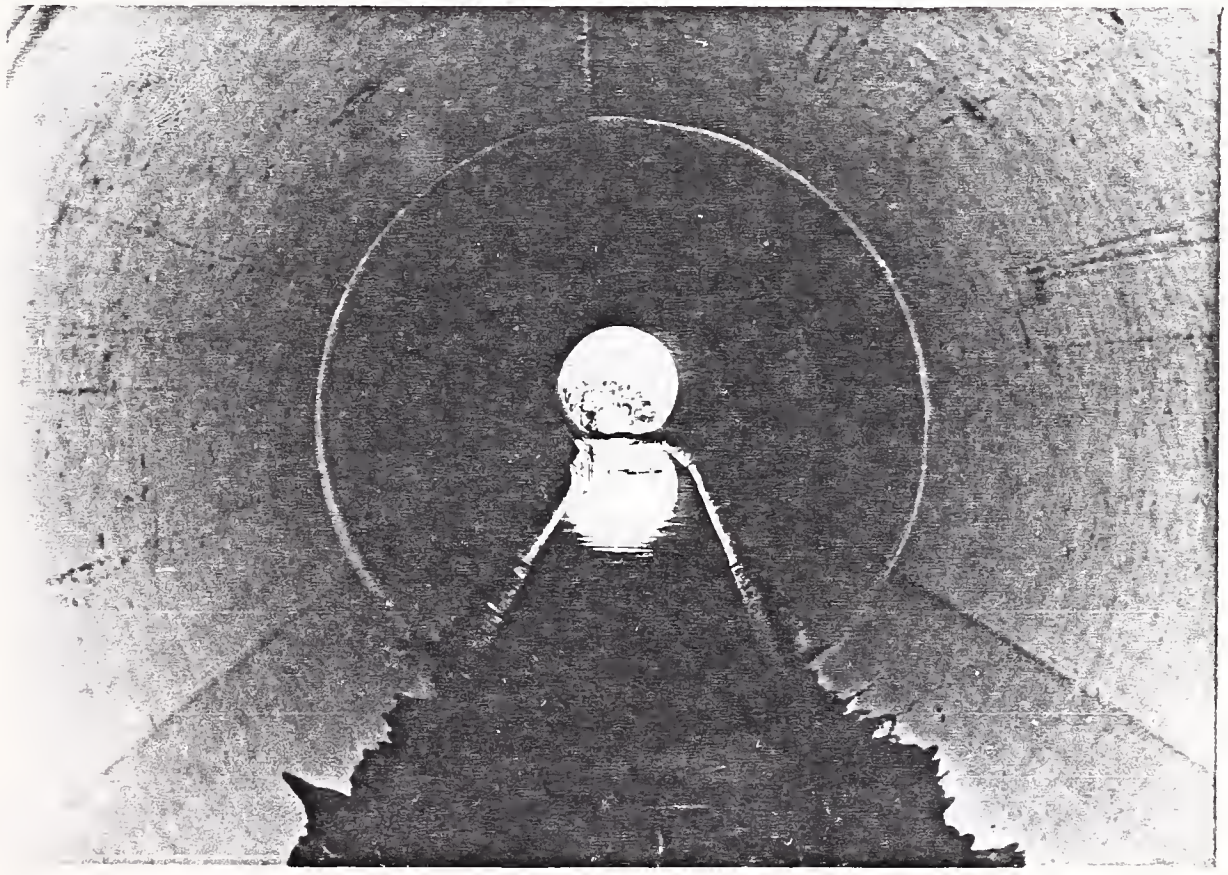


Photo No. 28 - Diversion Structure Conduit.
Left (west) conduit of the diversion structure is shown. Notice the standing water which is the result of settlement along the conduit. Horizontal misalignment is also visible.

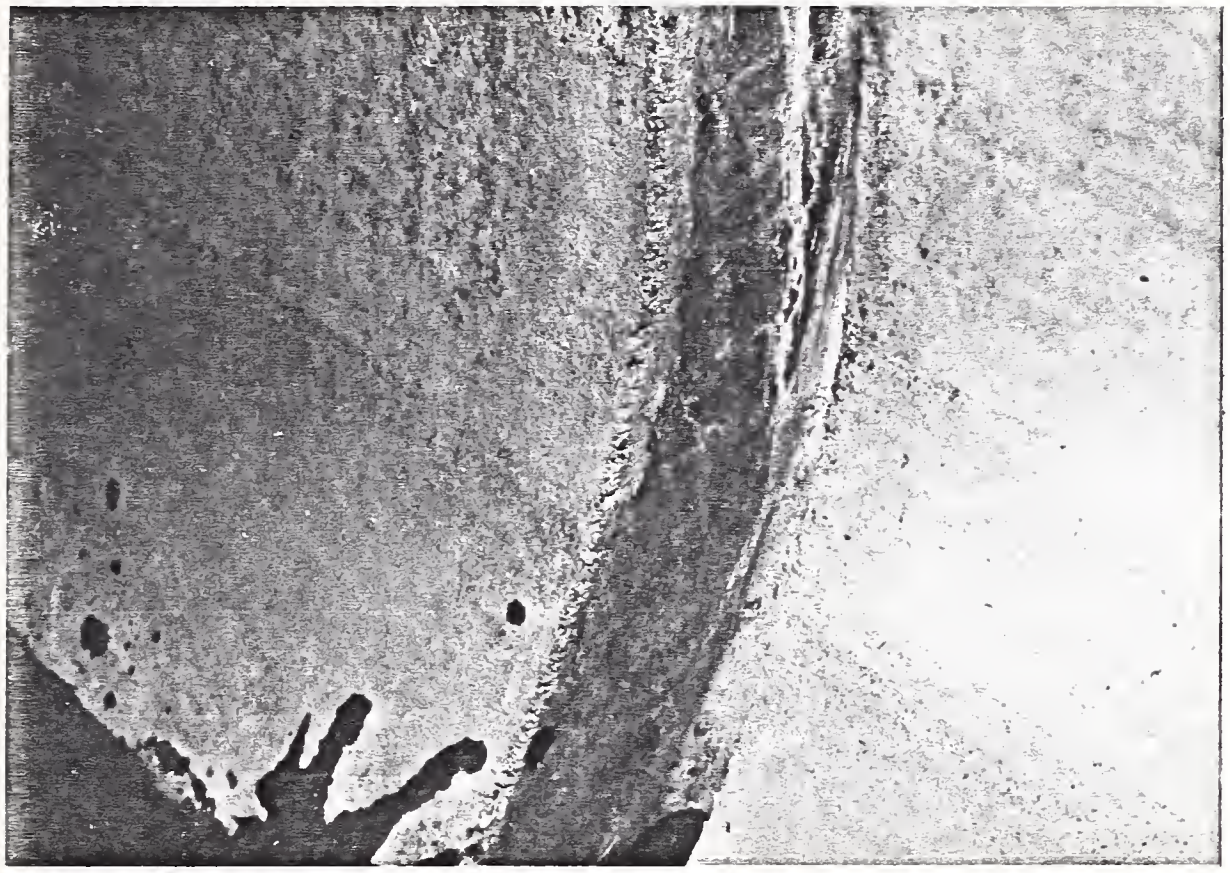


Photo No. 29 - Diversion Structure Conduit.
There is a 3½ inch gap at a joint in the left (west) conduit of the diversion structure. The joints in this conduit were never grouted.

Photo No. 30 - Diversion Structure Inlet.
Notice the gravel and debris that is accumulating at the inlet. The slidegate of the right (east) conduit is visible. Paint is peeling off of the trash rack.

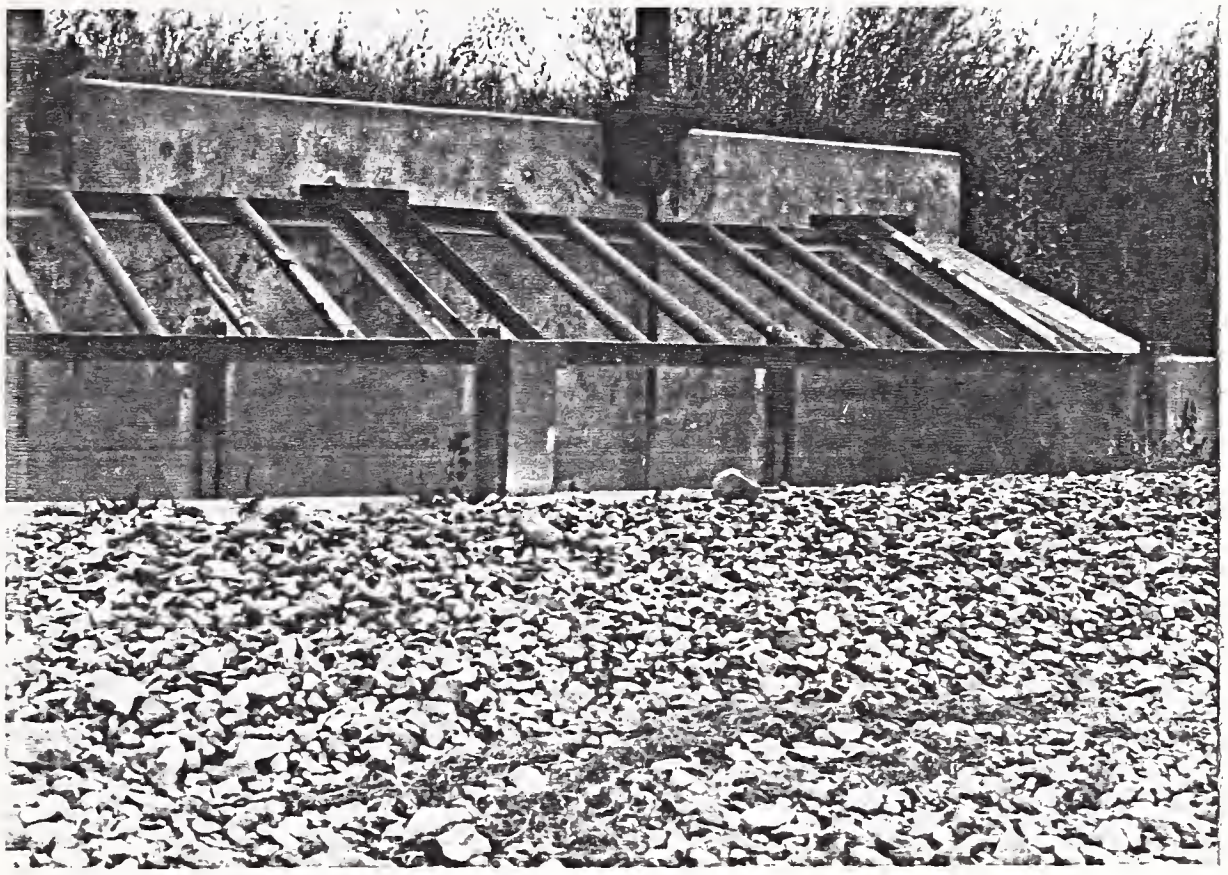


Photo No. 31 - Diversion Structure Inlet.
Notice that the approach slope to the inlet structure has gravel above the concrete inlet sill which has resulted in the deposit shown in Photo No. 30.

Photo No. 32 - Upstream Face of the Main Embankment.
The diversion inlet is the closer concrete structure. Notice the size and location of the gravel riprap protection. Erosion of the embankment above the gravel riprap is barely visible.

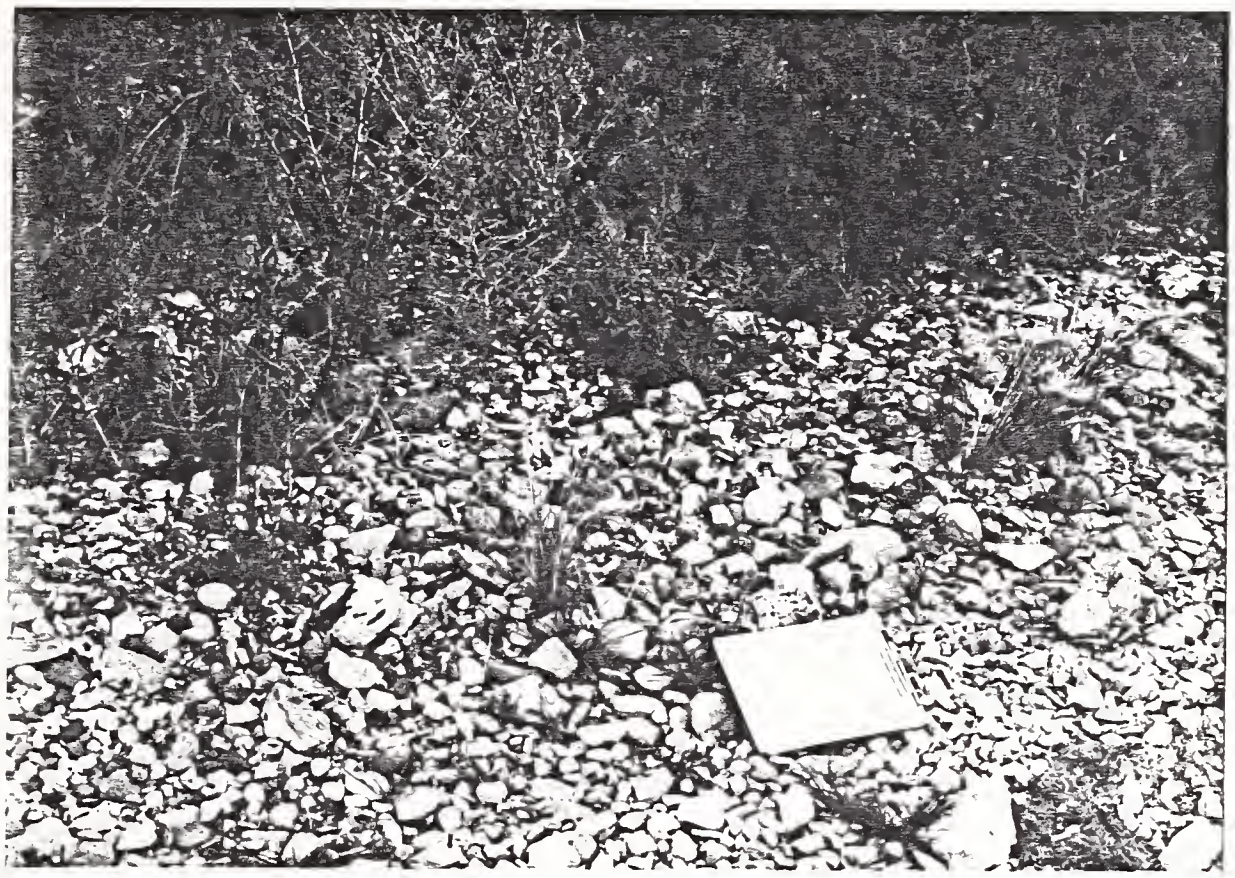


Photo No. 33 - Upstream Embankment Face Protection.
The riprap is predominately gravel with an average size of about 3 inches. There are some large pieces of sandstone scattered randomly over the face of the dam. Erosion of the embankment above the gravel riprap is barely visible.

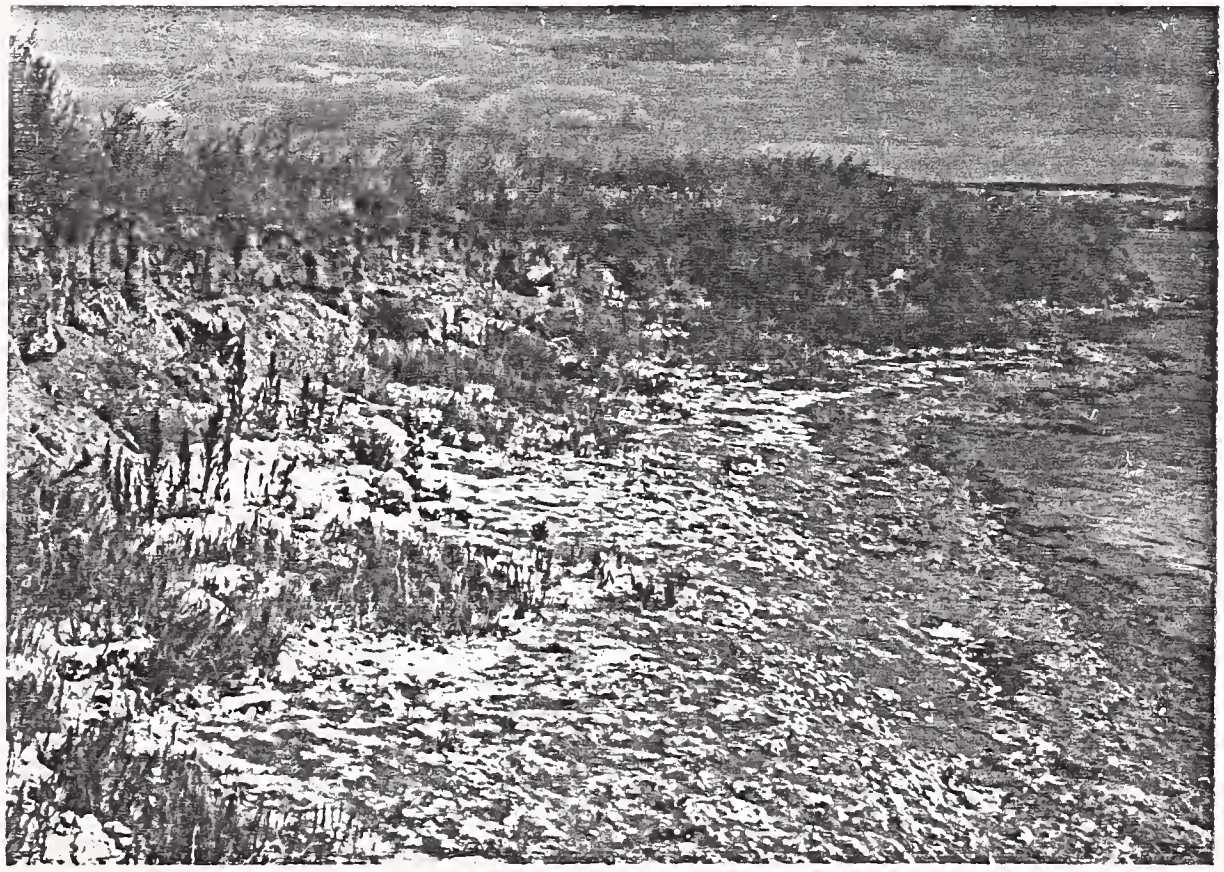


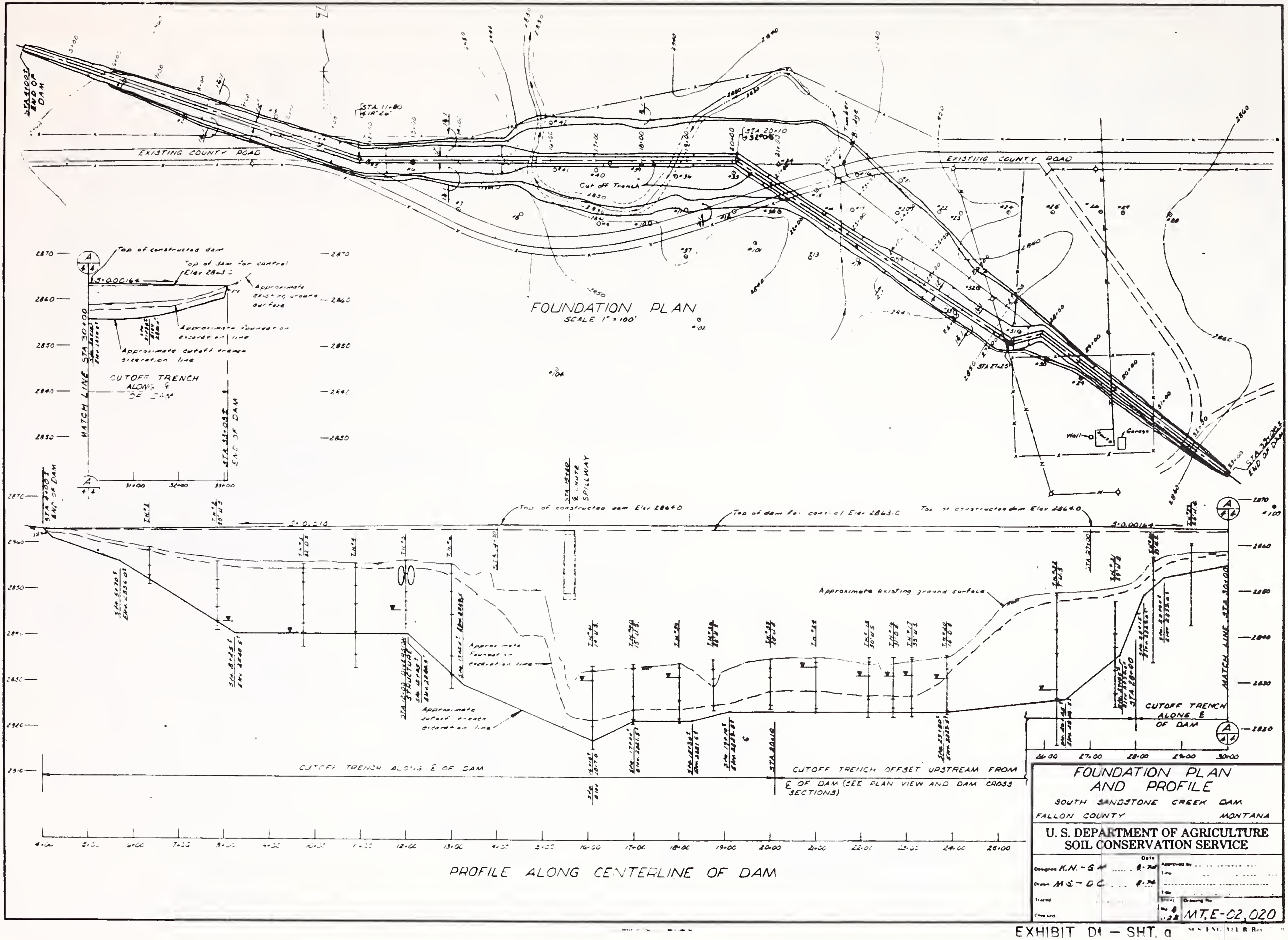
Photo No. 34 - Shoreline Erosion.
At some locations the wave action in the reservoir has cut vertical banks in the shoreline up to 4 feet high.

APPENDIX D

SOUTH SANDSTONE CREEK DAM

PROJECT DRAWINGS

EXHIBIT D1	CONSTRUCTION PLANS
EXHIBIT D2	DAM CREST PROFILE (OCT. 1979)
EXHIBIT D3	MEASURED EMBANKMENT SLOPES (SEPT. 1979)
EXHIBIT D4	SOILS DESIGN DATA
EXHIBIT D5	PRINCIPAL SPILLWAY CHUTE STABILITY



FOUNDATION PLAN AND PROFILE

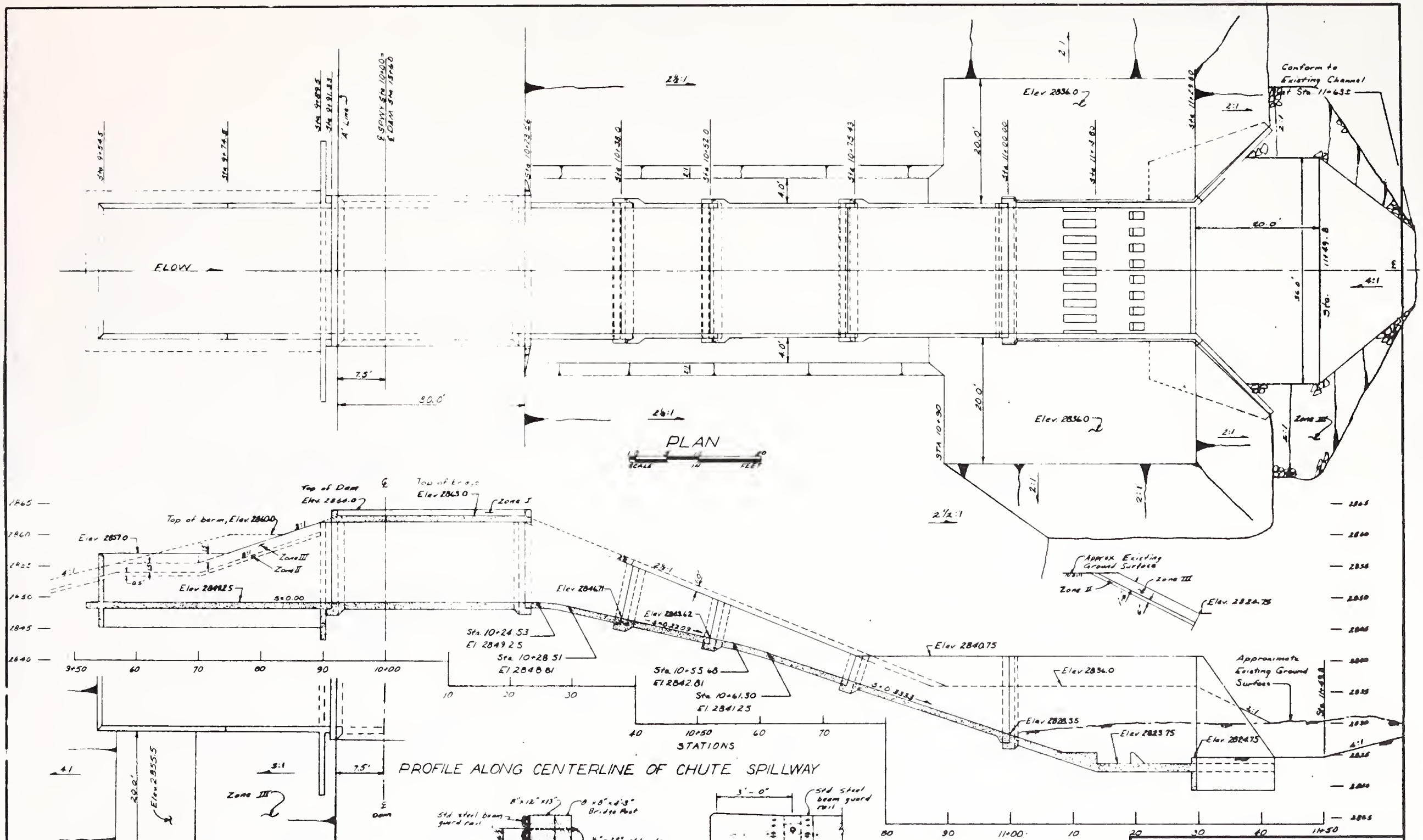
SOUTH SANDSTONE CREEK DAM

FALLON COUNTY MONTANA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed K.N.-G.M. Date 8-74
Drawn M.S.-D.C. Date 8-74
Traced
Checked
Approved by
Title
Sheet 1 of 2 sheets
Drawing No. MT,E-02,020

EXHIBIT D1 — SHT. a



VERTICAL CURVE DATA

CURVE NO.1		CURVE NO 2	
STA	ELEV.	STA	ELEV
10+24.53	2849.25	10+55.68	2842.81
10+25.53	2849.22	10+56.68	2842.58
10+26.53	2849.14	10+57.68	2842.33
10+27.53	2849.00	10+58.68	2842.06
10+28.51	2848.81	10+59.68	2841.77
		10+60.68	2841.46
		10+61.30	2841.25

PLAN AND PROFILE OF CHUTE SPILLWAY

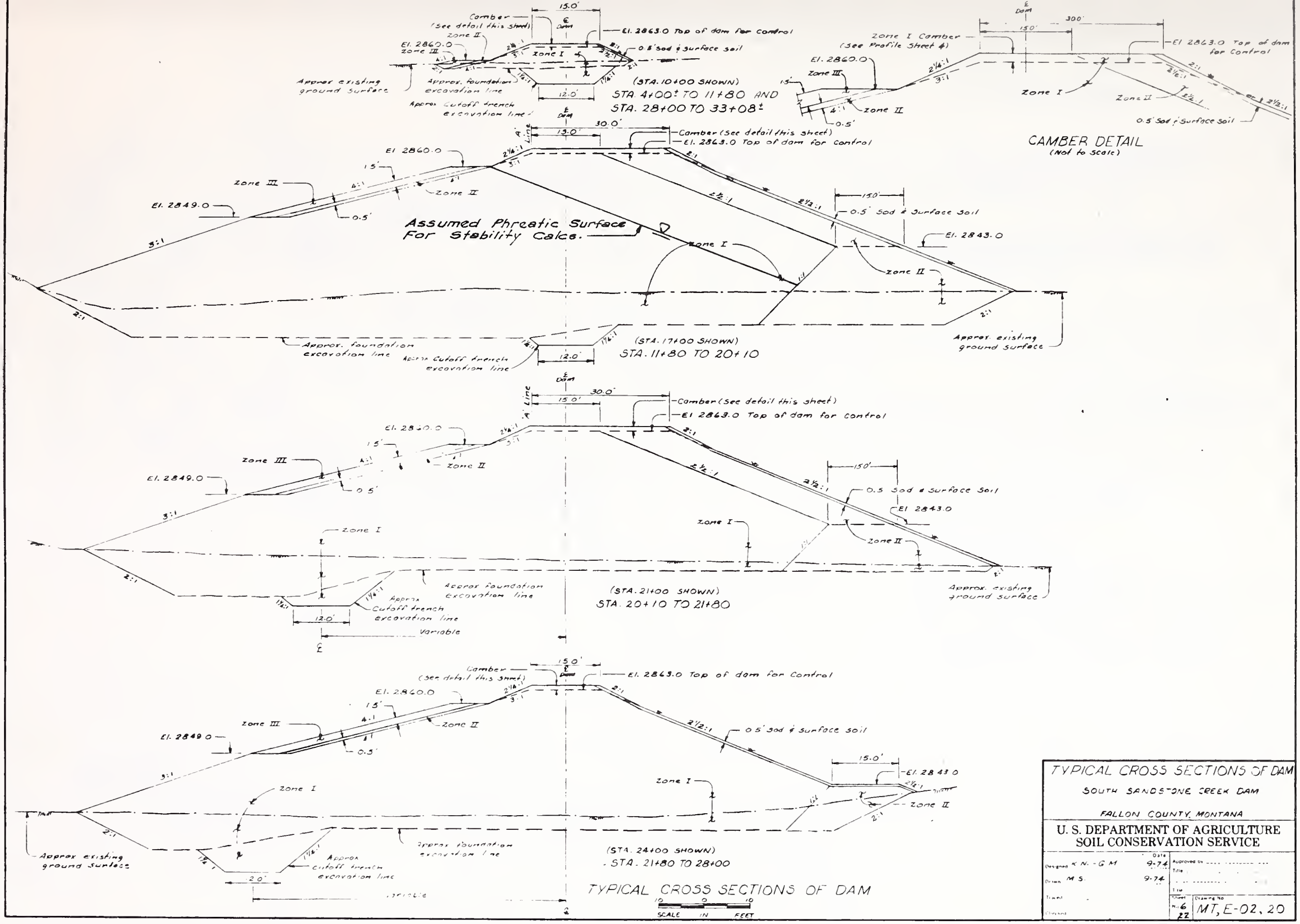
SOUTH SANDSTONE CREEK DAM
FALLON COUNTY, MONTANA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed G.M. 7-74
Drawn R.C. 7-74
Traced
Checked
Approved by
Title
Date
Drawing No.

MT. E-02,020

EXHIBIT 01 - SHT 6



TYPICAL CROSS SECTIONS OF DAM

SOUTH SANDSTONE CREEK DAM

FALLON COUNTY, MONTANA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed K. N. - G. M.	Date 9-74	Approved by	
Drawn M. S.	9-74	Title	
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Checked		Sheet No. 6 22	Drawing No. MT, E-02, 20

EXHIBIT D1 — SHT. c

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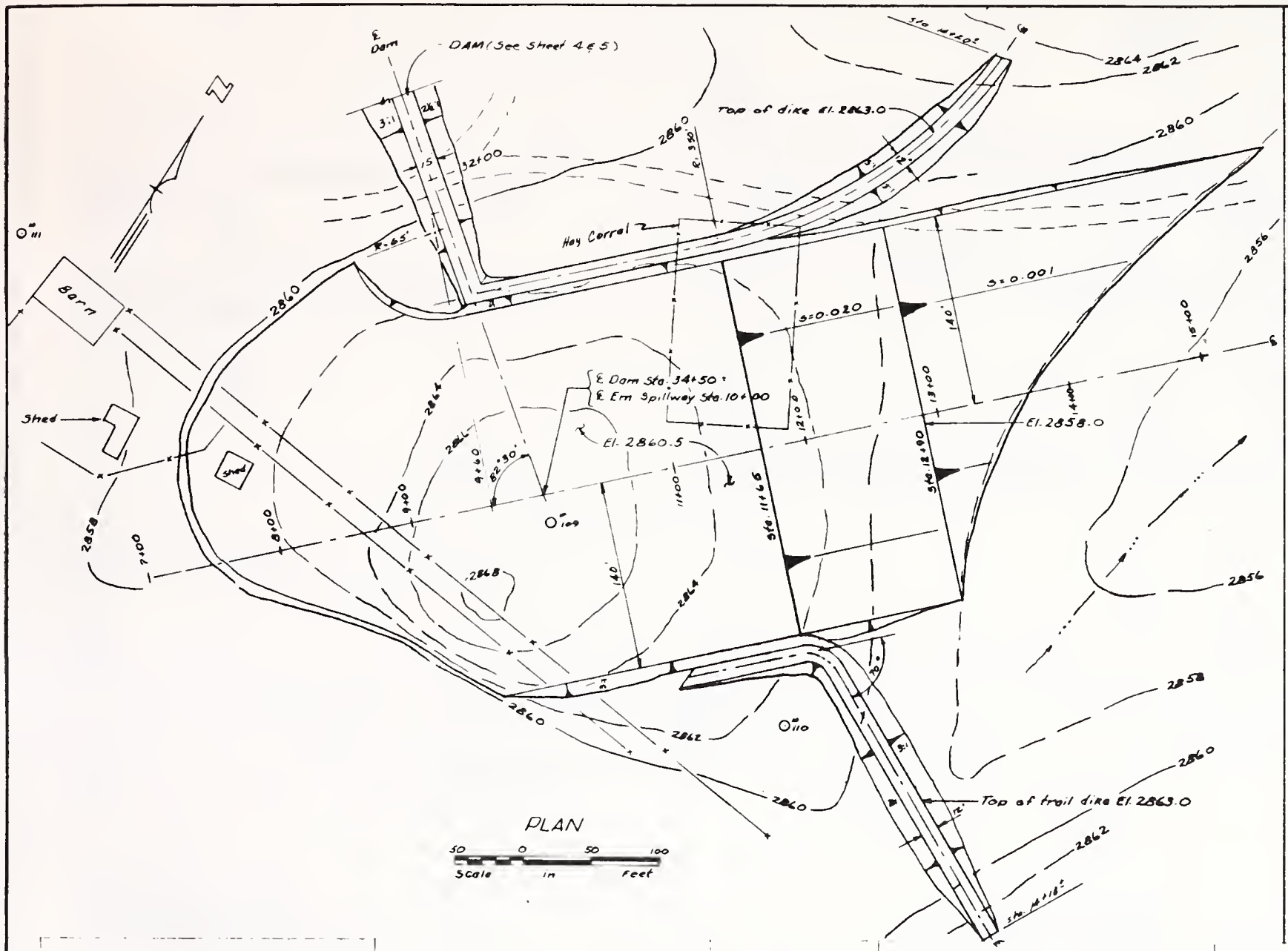
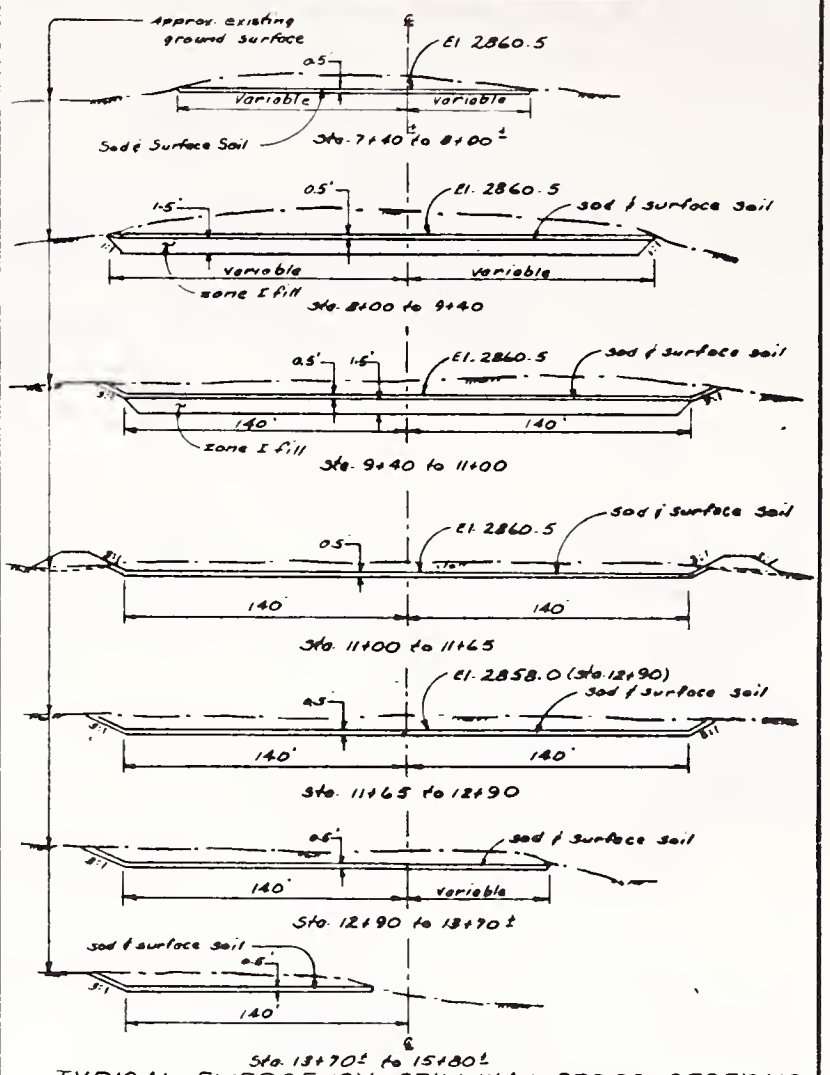
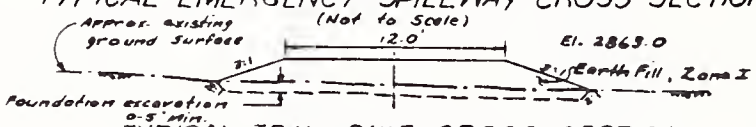
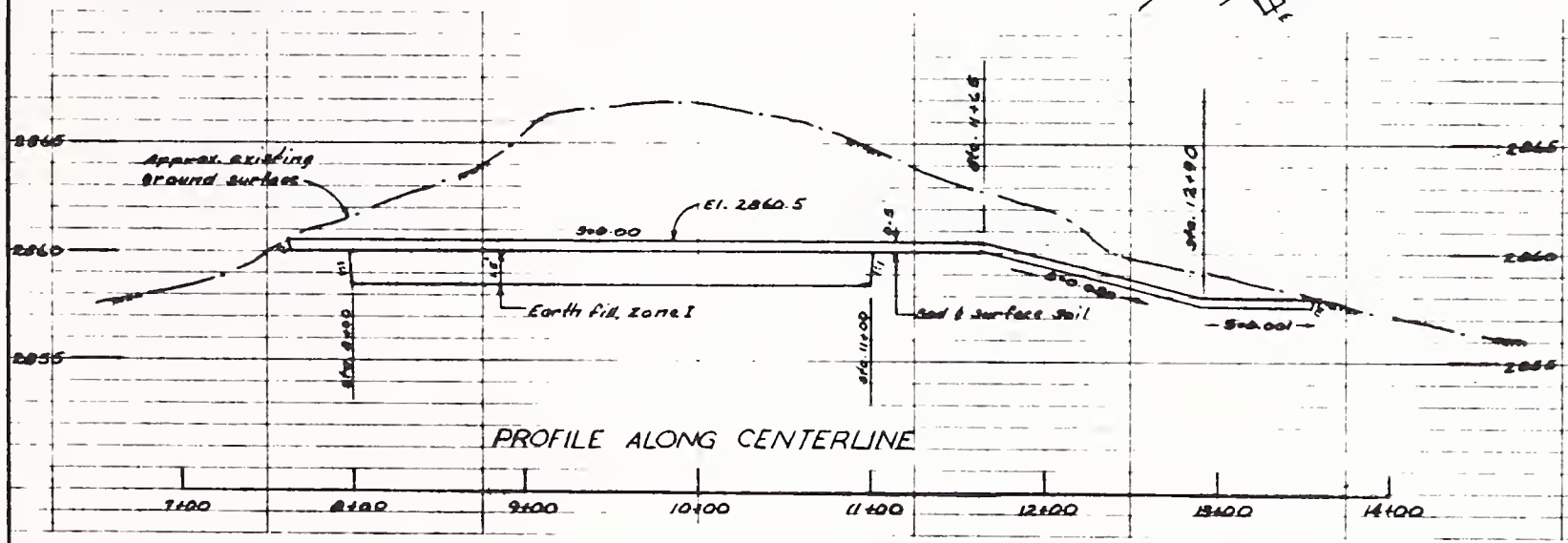




TYPICAL EMERGENCY SPILLWAY CROSS SECTIONS



TYPICAL TRAIL DIKE CROSS SECTION
(Not to Scale)



PROFILE ALONG CENTERLINE

EMERGENCY SPILLWAY DETAILS

SOUTH SANDSTONE CREEK DAM

FALLON COUNTY, MONTANA

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	Date	Approved by
K.N. - G.M. - R.S.	10-74	Title
Drawn		
M.S.	10-74	Title
Traced		
Checked		

Sheet No. 7 of 22

Drawing No. MT, E-02, 030

EXHIBIT D1 — SHT. d

Form SCS-318 (November 1966)

HALF PLAN

SECTIONAL ELEVATION

PLAN

ELEVATION

DETAIL (Not to scale)

SECTION

SECTION

SECTION

SECTION

VERTICAL CURVE NO.1	
STA	Elev.
10+24.53	2849.25
10+25.53	2849.22
10+26.53	2849.14
10+27.53	2849.00
10+28.51	2848.81

CHUTE SPILLWAY DETAILS

SOUTH SANDSTONE CREEK DAM

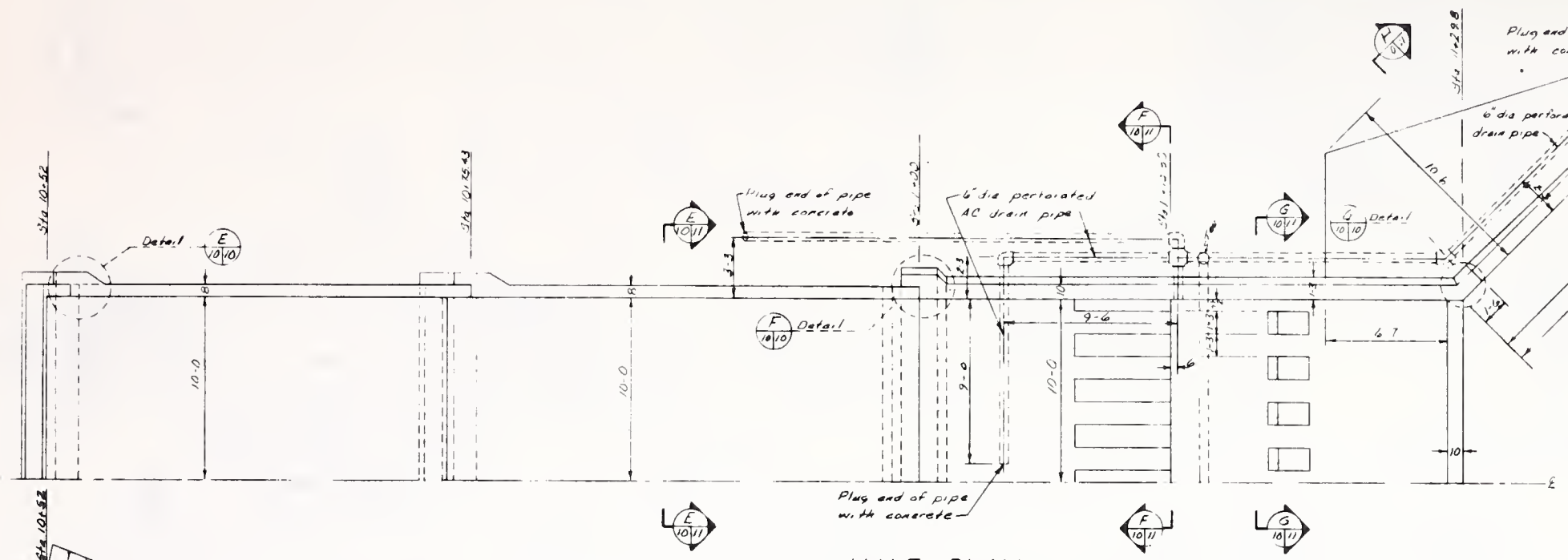
FALLON COUNTY MONTANA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

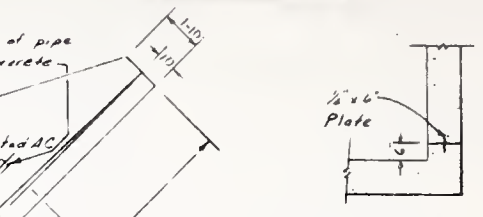
Designed K.N - G.M. 74
Drawn D.C. 74
Traced
Checked

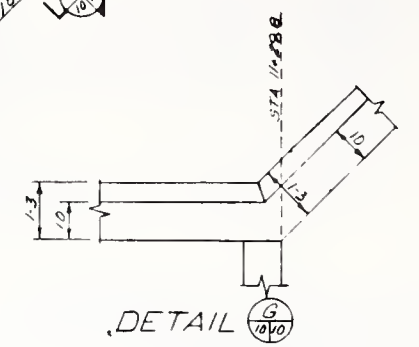
MT,E-02,020

EXHIBIT D1 – SHT. e

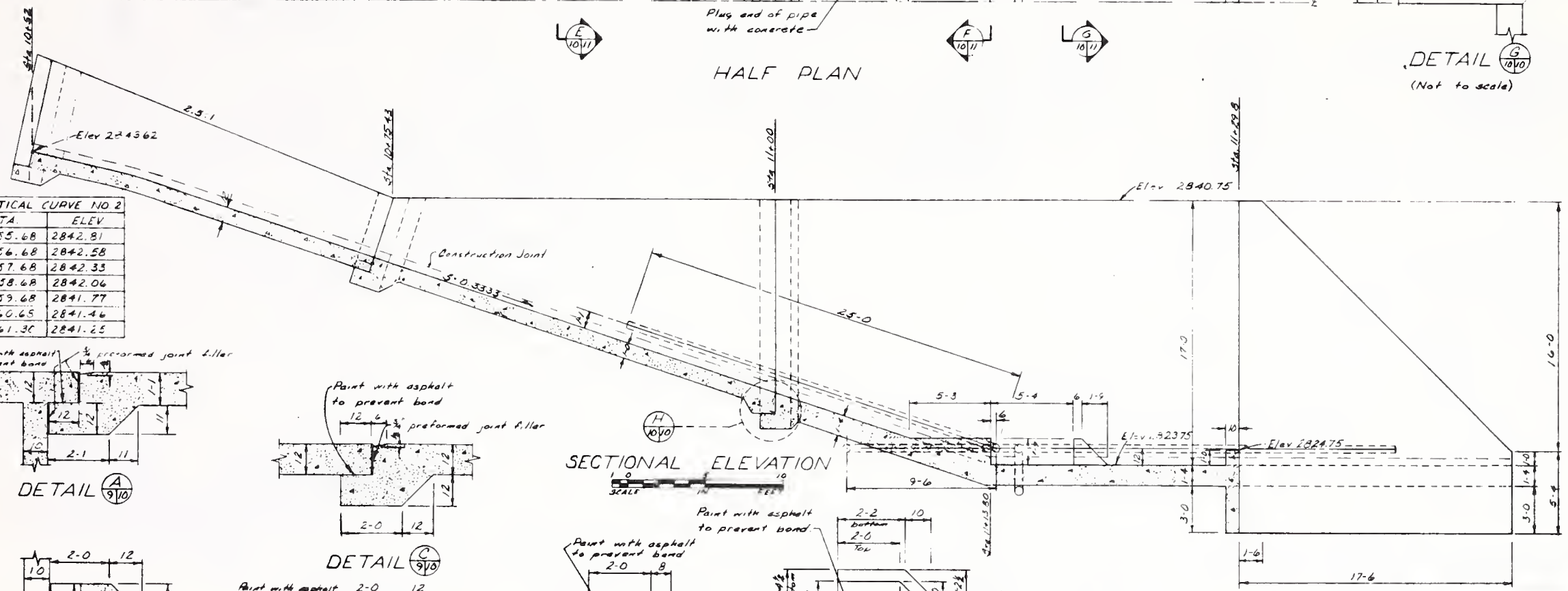


HALF PLAN





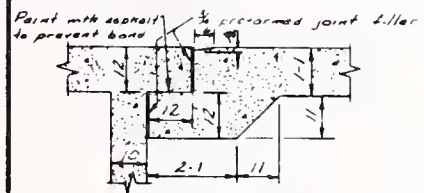
DETAIL G 10/10
(Not to scale)



SECTIONAL ELEVATION

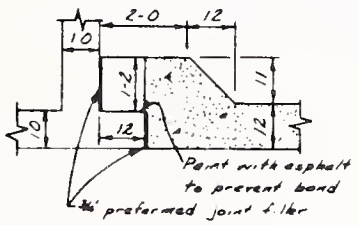
SCALE 0 5 10 FEET

VERTICAL CURVE NO 2	
STA.	ELEV
10+55.68	2842.81
10+56.68	2842.58
10+57.68	2842.33
10+58.68	2842.06
10+59.68	2841.77
10+60.65	2841.46
10+61.30	2841.25

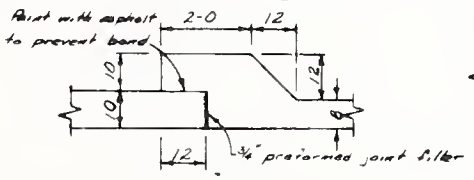


DETAIL A 9/10

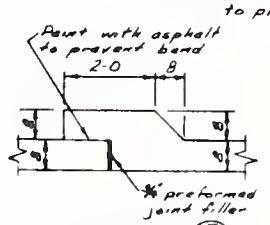
DETAIL C 9/10



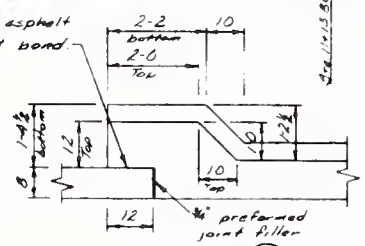
DETAIL B 9/10



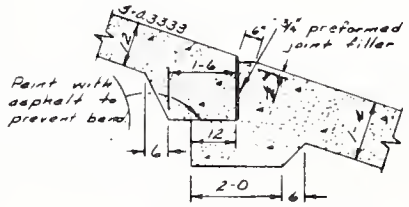
DETAIL D 9/10



DETAIL E 10/10



DETAIL F 10/10



DETAIL H 10/10

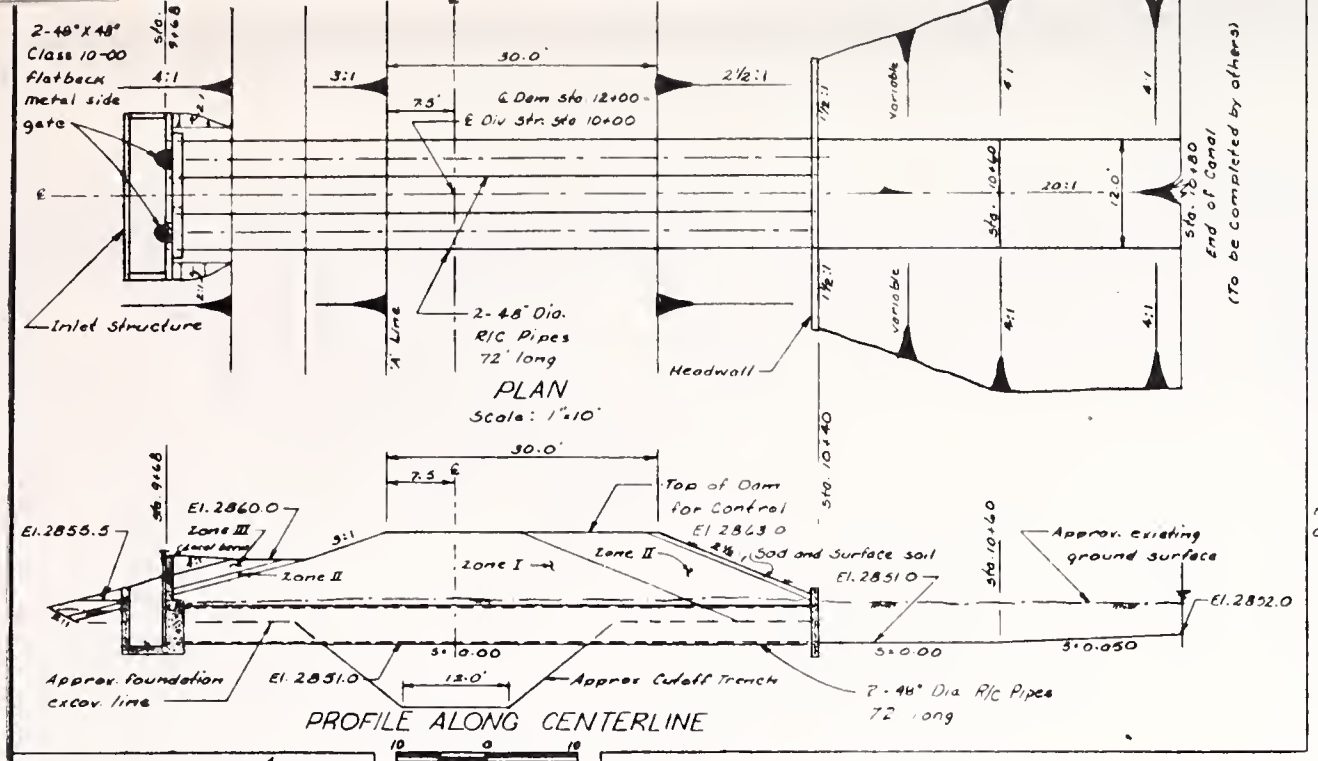
JOINT DETAILS
(Not to scale)

CHUTE SPILLWAY DETAILS
SOUTH SANDSTONE CREEK DAM
FALLON COUNTY MONTANA

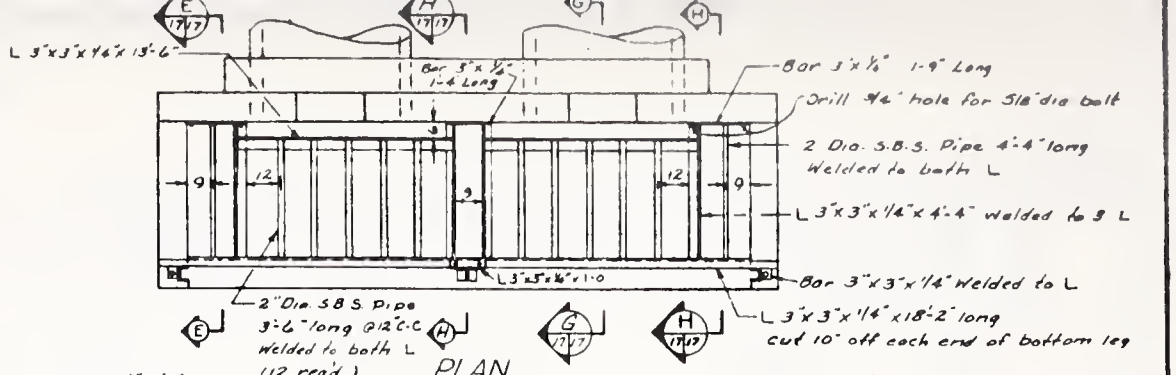
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed K.N.-G.M. Approved by
Drawn D.C. Title
Traced Drawing No.
Checked 22 MT,E-02,020

EXHIBIT D1 — SHT. f

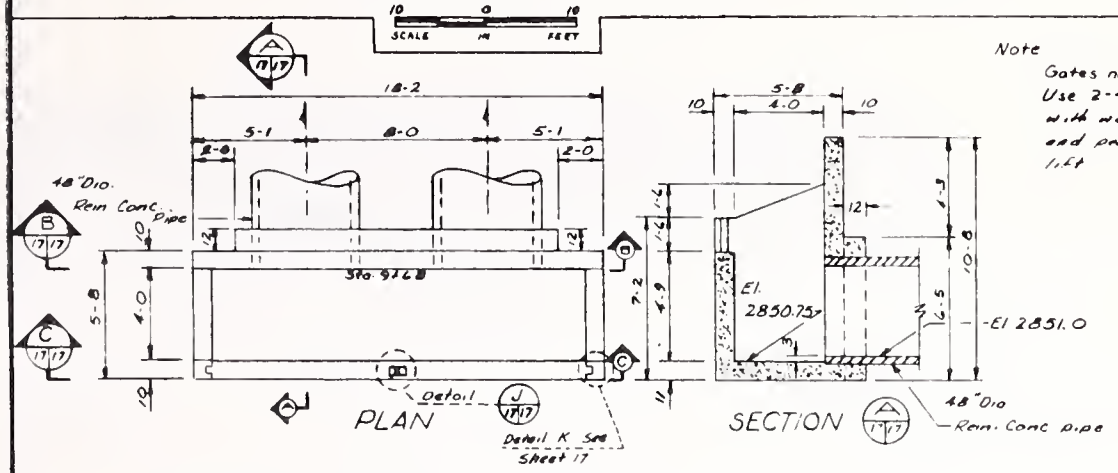


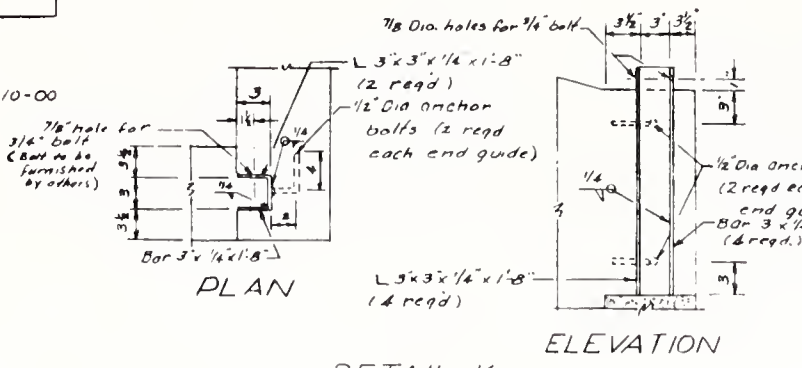
Note
Gates not shown.
Use 2-48"x48" class 10-00 with wall bracket and pedestal type lift

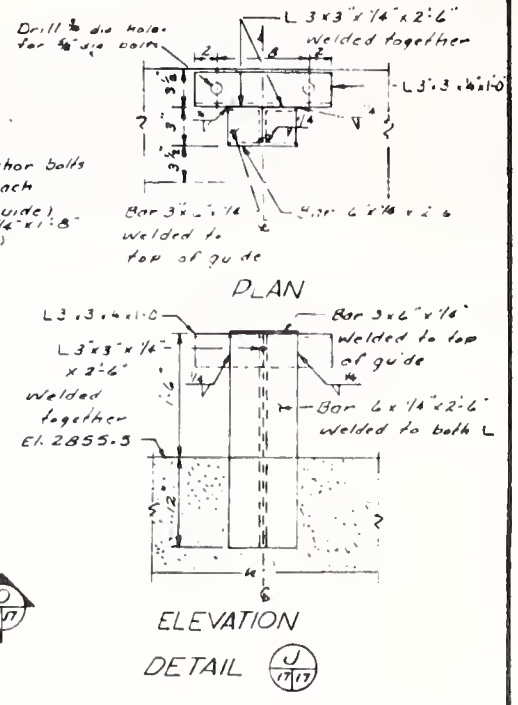

L 3"x3"x¼"x13'-6"
Bar 3"x½" 1'-4" Long
Bar 3"x½" 1'-9" Long
Drill ¾" hole for 5/8" dia bolt
2 Dia. S.B.S. Pipe 4'-4" long Welded to both L
L 3"x3"x¼"x4'-4" Welded to 3 L
L 3"x3"x¼"x1'-0
Bar 3"x3"x¼" Welded to L
L 3"x3"x¼"x18'-2" long cut 10" off each end of bottom leg
2"Dia. S.B.S. Pipe 3'-6" long @12"C-C Welded to both L (12 reqd.)
PLAN
Bar 3"x¼" 1'-9" Long (2 reqd.)
2"Dia. S.B.S pipe 4'-4" long (2 reqd.)
5/8"Dia. Self-drilling type Conc anchors (6 reqd)
L 3"x3"x¼"x18'-2
SECTION E
L 3"x3"x¼"x13'-6"
2"Dia. S.B.S. pipe 3'-6" long (12 reqd.) @12"C-C
L 3"x3"x¼"x18'-2
SECTION G
Bar 3"x¼" 1'-9" Long
L 3"x3"x¼"x4'-4" (2 reqd.)
L 3"x3"x¼"x18'-2"
L 3"x3"x¼"x1'-0 bolted to L 3"x3"x¼"x18'-2"
⅝"Dia. self-drilling type conc. anchor (6 reqd.)
SECTION H

Note: See sheet 19 for Stoplog Details.

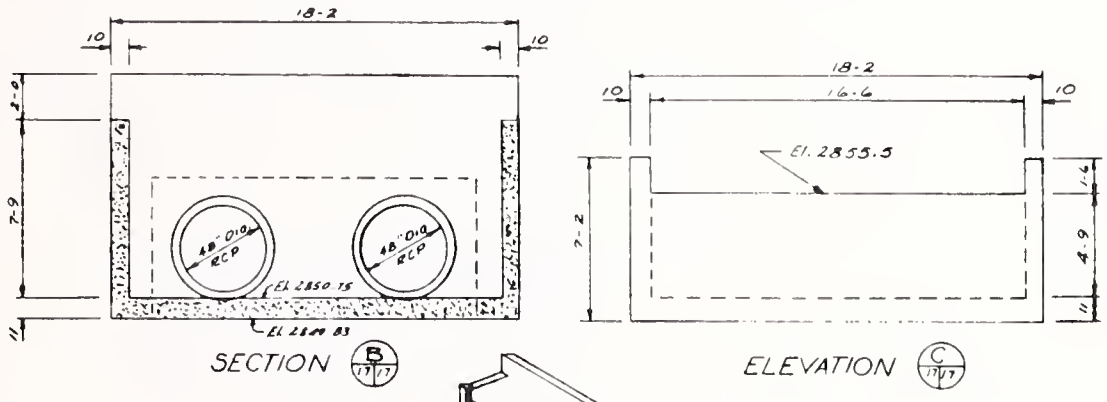
TRASH RACK DETAILS
Scale: 3/8"=1'-0"

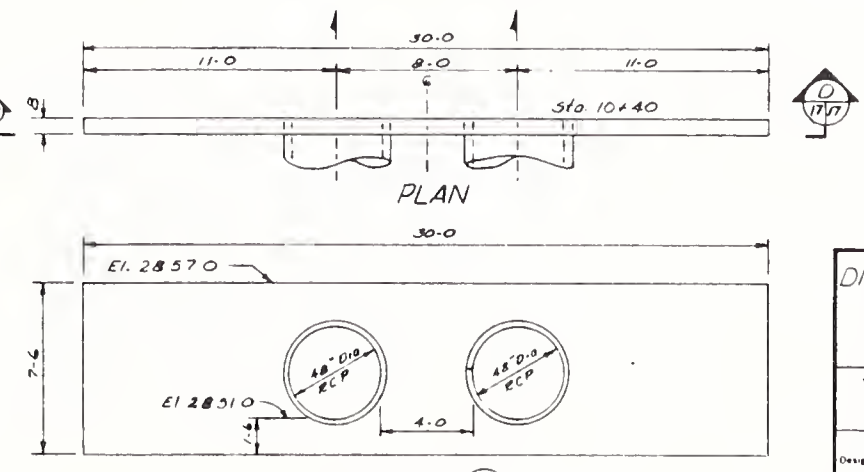



7/8 Dia. holes for ¾" bolt
L 3"x3"x¼"x1'-8" (2 reqd)
½" Dia anchor bolts (2 reqd each end guide)
7/8" hole for 3/4" bolt (Bolt to be furnished by others)
Bar 3"x½"x1'-8"
PLAN
L 3"x3"x¼"x1'-8" (4 reqd)
½" Dia anchor bolts (2 reqd each end guide)
Bar 3"x¼"x1'-8" (4 reqd.)
ELEVATION
DETAIL K


Drill ⅞ dia hole for ¾" dia bolt
L 3"x3"x¼"x2'-6" Welded together
L 3"x3"x¼"x1'-0
Bar 3"x¼" Welded to top of guide
PLAN
L 3"x3"x¼"x1'-0
L 3"x3"x¼" x 2'-6" Welded together
El. 2855.3
Bar 3"x6"x¼" Welded to top of guide
Bar 6"x¼"x2'-6" Welded to both L
ELEVATION
DETAIL J

STOPLOG GUIDE DETAILS
(Not to scale)





DIVERSION STRUCTURE DETAILS

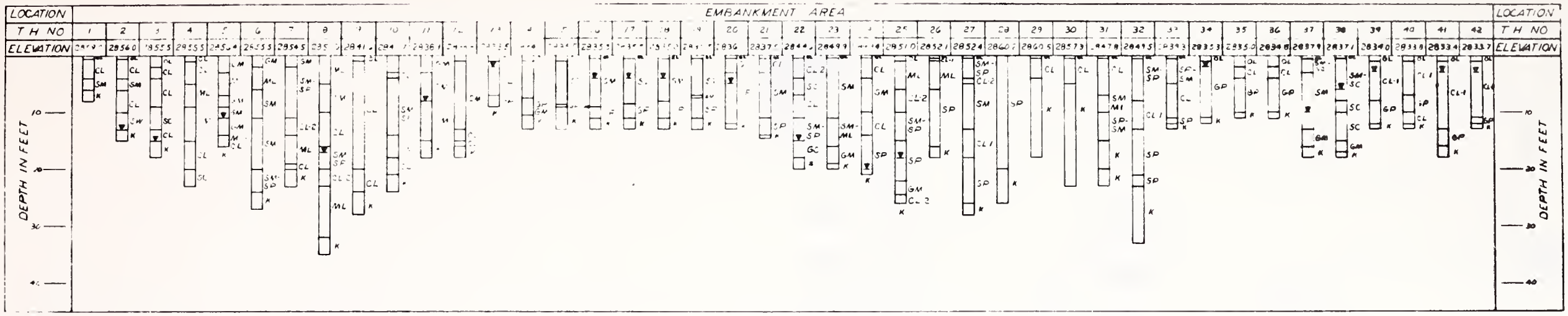
SOUTH SANDSTONE CREEK DAM
FALLON COUNTY, MONTANA

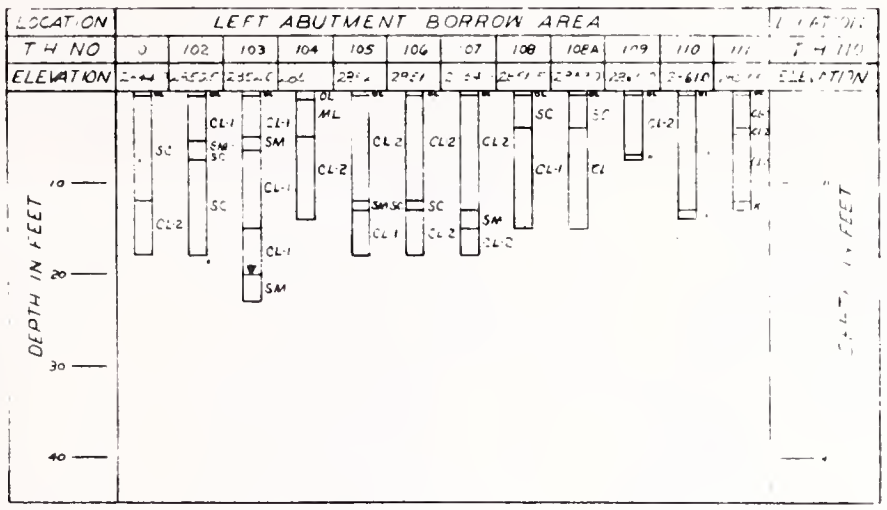
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed J. M. Date 10-74 Approved by
Drawn M S Date 10-74 Title
Traced Date
Checked Sheet No 2 Drawing No MT,E-02,07

EXHIBIT D1 — SHT. 9

BORING LOGS





SOIL BORING LEGEND

- GP Poorly graded gravels, gravels - sand mixtures, little or no fines
- GM Silty gravels, gravel - sand - silt mixtures
- GC Clayey gravels; gravel - sand - clay mixtures.
- SW Well graded sand, sand - gravel mixtures little or no fines.
- SP Poorly graded sands; gravelly - sand, little or no fines
- SM Silty sand; sand - silt mixtures.
- SC Clayey sand, sand - clay mixtures
- ML Silts, silty, Very fine sands, sandy or clayey silts.
- CL Clays of low liquid limit and medium plasticity, silty, sandy or gravelly clays and clayey silts
- CL-1 Clays of low to medium plasticity
- CL-2 Clays of medium to high plasticity
- OL Organic silts and organic silty clays of low liquid limit and low plasticity
- K Bedrock

TEST HOLE EXCAVATION DATE

TEST HOLE NUMBER	DATE LOGGED
1 Thru 20	4-4-72
21 Thru 41	4-5-72
40 Thru 42, 101 Thru 111	4-6-72

Notes

1 Soils classified in accordance with the Unified Soil Classification System

2 All soil classification symbols are based on field identification. All soil logs shown are abridged. Complete drilling logs and geology reports are available for bidders inspection at the Soil Conservation Service Office in Sumner, Montana.

3 ▼ Denotes water level as measured in field at the date of logging. Depth to water table was not logged in all holes.

4 Some test holes are offset of ℄, for location see plan of dam and reservoir, sheets 4 & 5

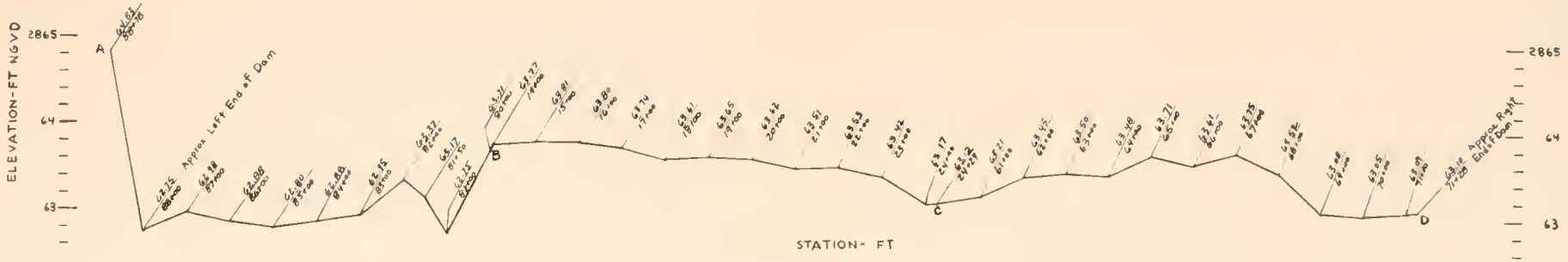
BORING LOGS
SOUTH SANDSTONE CREEK DAM
FALLON COUNTY, MONTANA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed KN - G.M 8-74 Submitted by
Drawn R.N 8-74
Traced
Checked

Title 22 Drawing No. MT,E-02,020
22

EXHIBIT D1 — SHT h



PROFILE VIEW - SECTION A-B-C-D

0 100 200 400 FT
Horizontal Scale

NOTES:

1. Elevations based on using elevation at lip of diversion structure inlet = 2855.5' NGVD as beginning elevation, as shown on const. drawings.
2. Stationing shown is not equivilant to stationing on construction drawings.

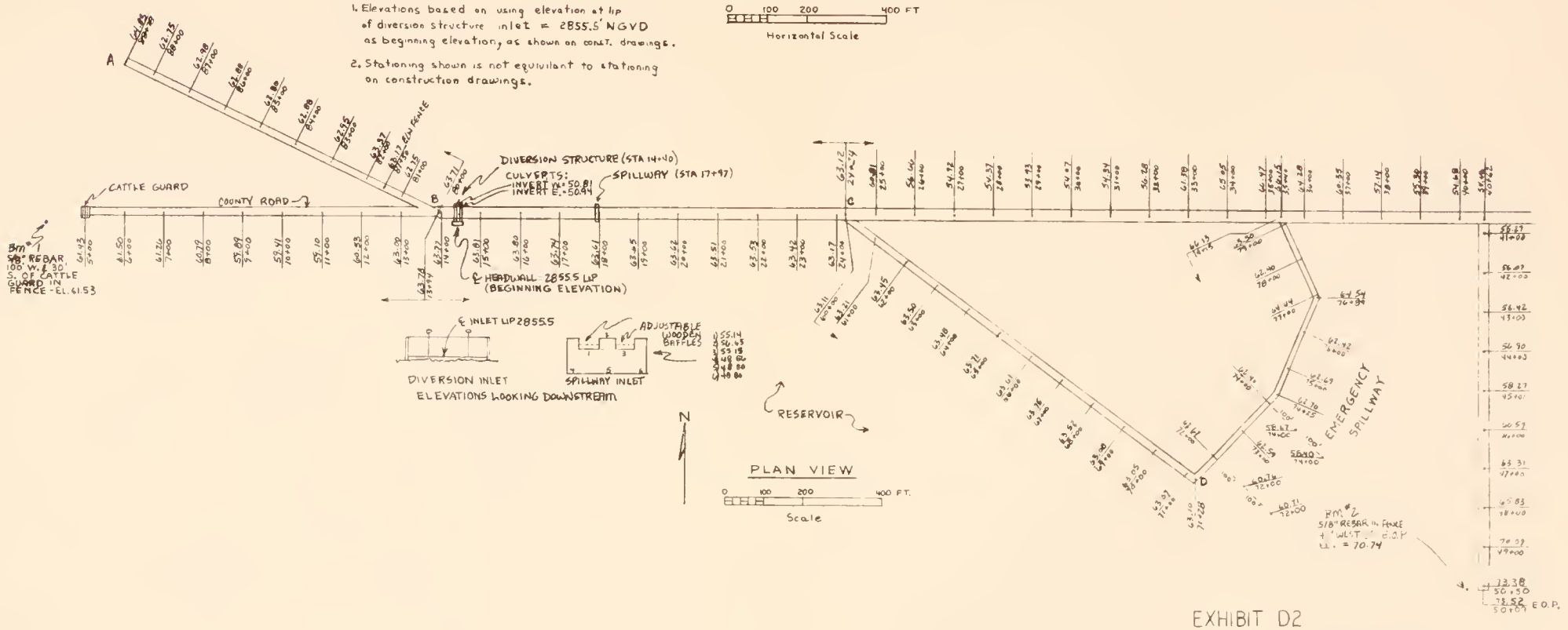


EXHIBIT D2
PROFILE ALONG CREST ℄
SOUTH SANDSTONE CREEK DAM
HKM ASSOCIATES - OCT 10, 1979
JOB NO 7M140.107

HKM ASSOCIATES COMPUTATION SHEET

By	Date	Project No.	Sheet 1 of 3
DRC	11-6-79	7M140.107	
Chkd by	Date	Name	
		South Sandstone Creek Dam Crest Survey	
Details		Feature	
		Station - Elevation Tabulation	

STATION FT	ELEVATION FT-NGVD	DESCRIPTION
	2861.53	B.M. #1 - 5/8" Rebar 100'W. & 30'S. OF C. GUARD
5+00	2861.43	℄ Cattle Guard
6+00	2861.50	
7+00	2861.26	
8+00	2860.79	
9+00	2859.89	
10+00	2859.41	
11+00	2859.10	
12+00	2860.53	
13+00	2863.00	
13+94	2863.78	
14+00	2863.77	
	2855.50	℄ Diversion Inlet Lip = Starting Point*
14+40	2850.81	Diversion Outlet Invert, West
	2850.94	Diversion Outlet Invert, East
15+00	2863.81	
16+00	2863.80	
17+00	2863.74	
	2856.65	Top of Spillway Inlet Structure, Center
	2855.14	Top of Spillway Inlet Lip, West
17+97	2855.15	Top of Spillway Inlet Lip, East
	2848.80	Bot. of Spillway Inlet, Center
	2848.86	Bot. of Spillway Inlet, West
	2848.80	Bot. of Spillway Inlet, East
18+00	2863.61	
19+00	2863.65	
20+00	2863.62	
21+00	2863.51	
22+00	2863.53	
23+00	2863.42	
24+00	2863.17	
24+24	2863.12	
25+00	2860.81	
26+00	2856.66	
27+00	2854.92	
28+00	2854.37	
29+00	2853.93	
30+00	2854.07	
31+00	2854.34	

EXHIBIT D2

Western Printing-Billings, Montana

HKM ASSOCIATES COMPUTATION SHEET

By	Date	Project No.	Sheet 2 of 3
DRC	11-6-79	7M140.107	
Chkd by	**Date**	**Name**	
		South Sandstone Creek Dam Crest Survey	
Details		**Feature**	
		Station - Elevation Tabulation	

STATION FT	ELEVATION FT-NGVD	DESCRIPTION
32+00	2856.28	
33+00	2861.38	
34+00	2865.05	
35+00	2866.47	
35+40	2866.15	
36+00	2864.28	
37+00	2860.35	
38+00	2857.14	
39+00	2855.30	
40+00	2854.68	
40+62	2854.46	
41+00	2855.27	
42+00	2856.07	
43+00	2856.42	
44+00	2856.90	
45+00	2858.27	
46+00	2860.59	
47+00	2863.31	
48+00	2865.83	
49+00	2870.09	
50+00	2873.38	
50+09	2873.52	E.O.P.
—	2870.74	B.M.#2- 5/8" Rebar in Fence 42' W of E.O.P.
60+00	2863.11	
61+00	2863.21	
62+00	2863.45	
63+00	2863.50	
64+00	2863.48	
65+00	2863.71	
66+00	2863.61	
67+00	2863.75	
68+00	2863.52	
69+00	2863.08	
70+00	2863.05	

EXHIBIT D2

HKM ASSOCIATES COMPUTATION SHEET

By	Date	Project No.	Sheet 3 of 3
DRC	11-6-79	7M140.107	
Chkd by	**Date**	**Name**	
		South Sandstone Creek Dam Crest Survey	
Details		**Feature**	
		Station - Elevation Tabulation	

STATION FT	ELEVATION FT NGVD	DESCRIPTION
71+00	2863.07	
71+28	2863.10	Approx. Right End of Dam
72+00	2862.67	
73+00	2862.59	
74+00	2862.40	
74+25	2862.70	
75+00	2862.69	
76+00	2862.42	
76+89	2864.54	
77+00	2864.44	
78+00	2862.40	
79+00	2865.50	
79+15	2866.13	
80+00	2863.71	
81+00	2862.75	
81+50	2863.17	E/W Fence
82+00	2863.37	
83+00	2862.95	
84+00	2862.88	
85+00	2862.80	
86+00	2862.88	
87+00	2862.98	
88+00	2862.75	Approx. Left End of Dam
88+78	2864.83	

* NOTE:
Starting elevation at inlet lip of diversion structure based on assumption of no settlement of the diversion structure since construction

EXHIBIT D2

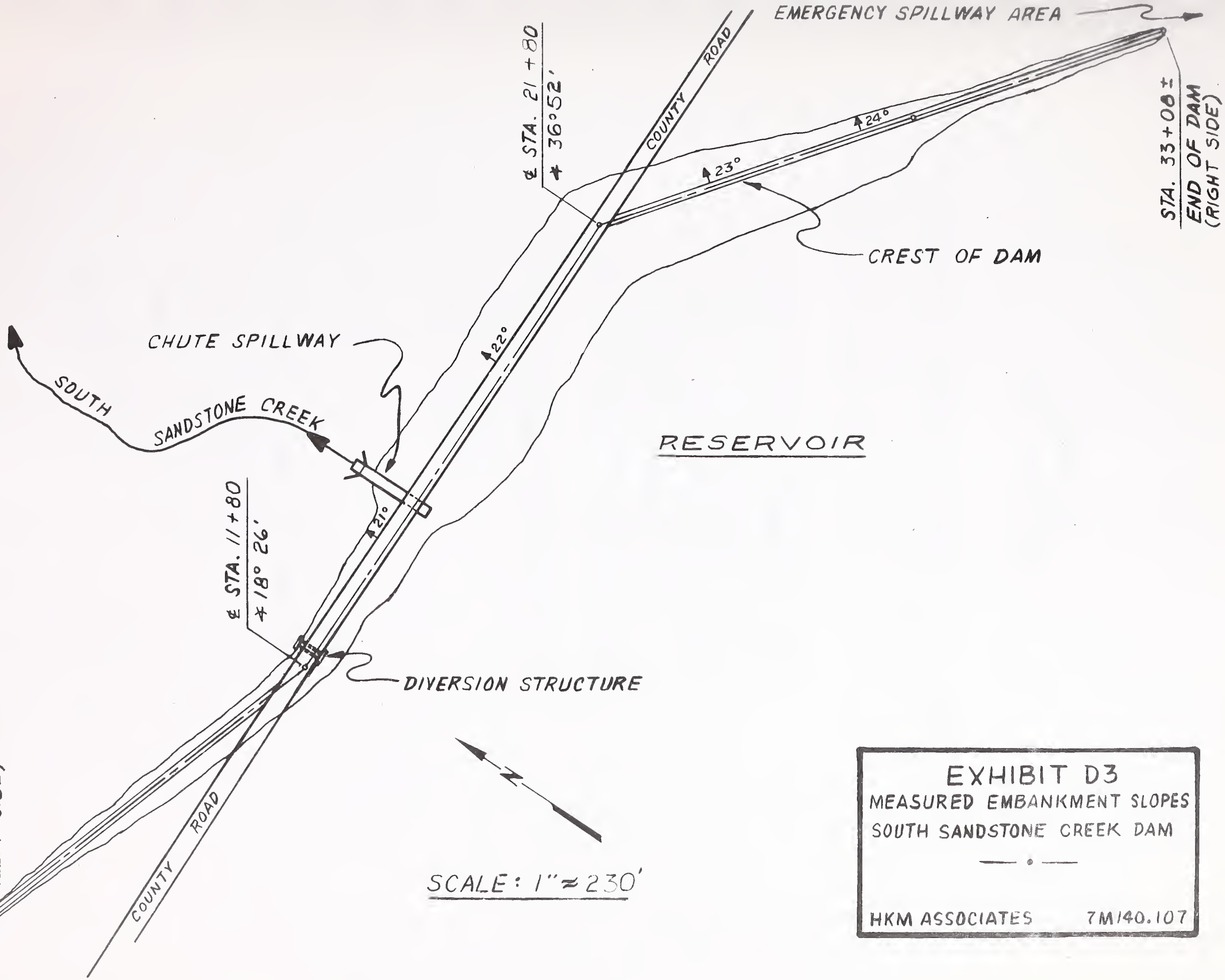


EXHIBIT D3

MEASURED EMBANKMENT SLOPES

SOUTH SANDSTONE CREEK DAM

HKM ASSOCIATES 7M140.107

EXHIBIT D4

SOILS DESIGN DATA

The soil properties assigned by the SCS to the various zones (based on experience with similar soils) and used in the slope stability analysis were:

1) Zone I (central impervious zone)

γ dry = 106.0 pcf (unit weight)

γ sat. = 129.1 pcf (unit weight)

C = 200 psf (cohesion value)

Φ = 16° (internal friction angle)

2) Zone II (downstream pervious zone)

γ dry = 120 pcf

γ sat. = 126 pcf

C = 0

Φ = 34°

3) Foundation (upper thin seam located on the upstream side)

γ dry = 95 pcf

γ sat. = 110 pcf

C = 200 psf

Φ = 12°

4) Foundation (deep soils)

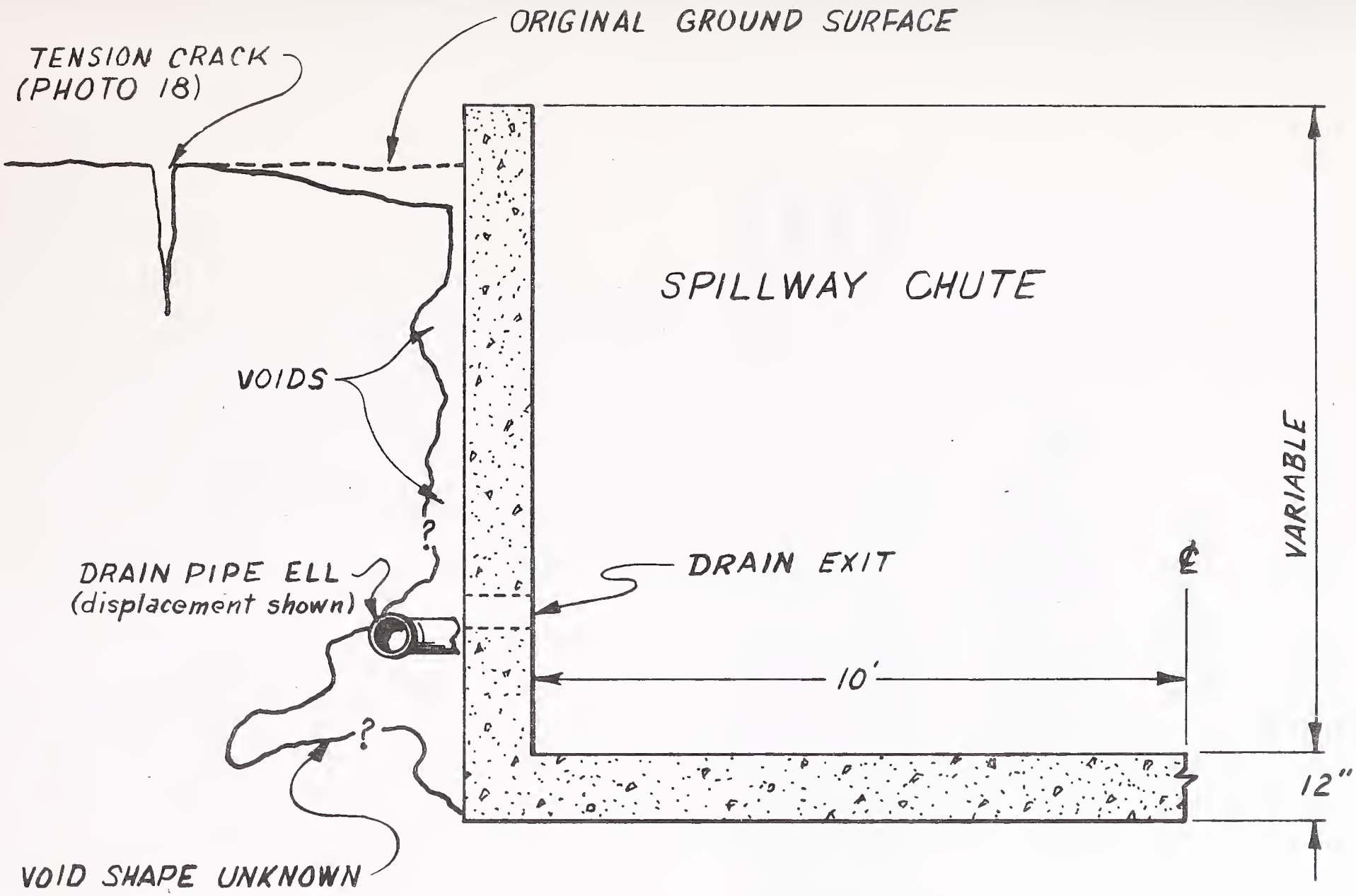
γ dry = 120 pcf

γ sat. = 135 pcf

C = 0

ϕ = 34°

Source: SCS "Work Plan" File, Reference 1; results interpreted by HKM Associates



SCALE: 3/8" = 1 FOOT

EXHIBIT D5

PRINCIPAL SPILLWAY

CHUTE STABILITY

SOUTH SANDSTONE CREEK DAM

HKM ASSOCIATES 7M140.107

APPENDIX E

SOUTH SANDSTONE CREEK DAM
ENGINEERING DATA

EXHIBIT E1	RESERVOIR ELEVATION - CAPACITY TABLE
EXHIBIT E2	RESERVOIR ELEVATION - CAPACITY CURVE
EXHIBIT E3	DISCHARGE RATING TABLE
EXHIBIT E4	DISCHARGE RATING CURVES

EXHIBIT E1

RESERVOIR ELEVATION-CAPACITY TABLE

SOUTH SANDSTONE DAM

Reservoir Elevation-Ft. NGVD	Reservoir Capacity-Acre-Ft.
2830	0
2834	0.08
2836	0.95
2838	8.48
2840	24.94
2842	54.07
2844	98.49
2846	156.94
2848	234.80
2850	335.55
2852	457.03
2854	604.48
2856	792.03
2858	1042.99
2860	1355.70
2863	1970.00

SOURCE: SCS Design Files

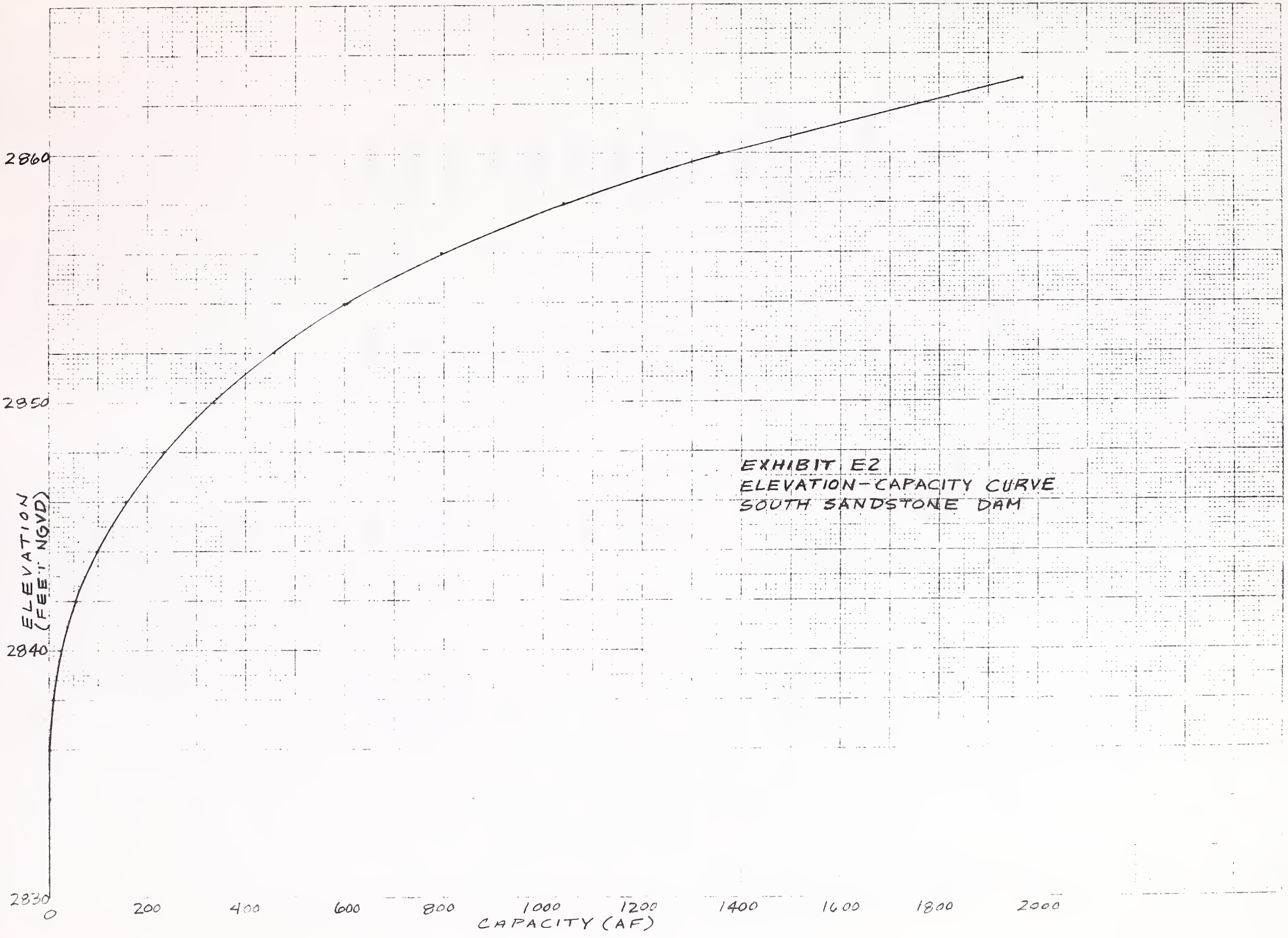


EXHIBIT E2
ELEVATION-CAPACITY CURVE
SOUTH SANDSTONE DAM

EXHIBIT E3

SOUTH SANDSTONE CREEK DAM

RATING TABLE

Elevation (Ft,NGVD)	Diversion Works (cfs)	Principal Spillway (cfs)	Emergency Spillway (cfs)
2855.5	0		
2856.7	67	0	
2857.0	94	40	
2858.0	206	300	
2859.0	300	740	
2860.0	335	1320	
2860.7	358	1782	0
2861.0	367	2000	100
2862.0	397	2860	800
2863.0	424	3800	2050

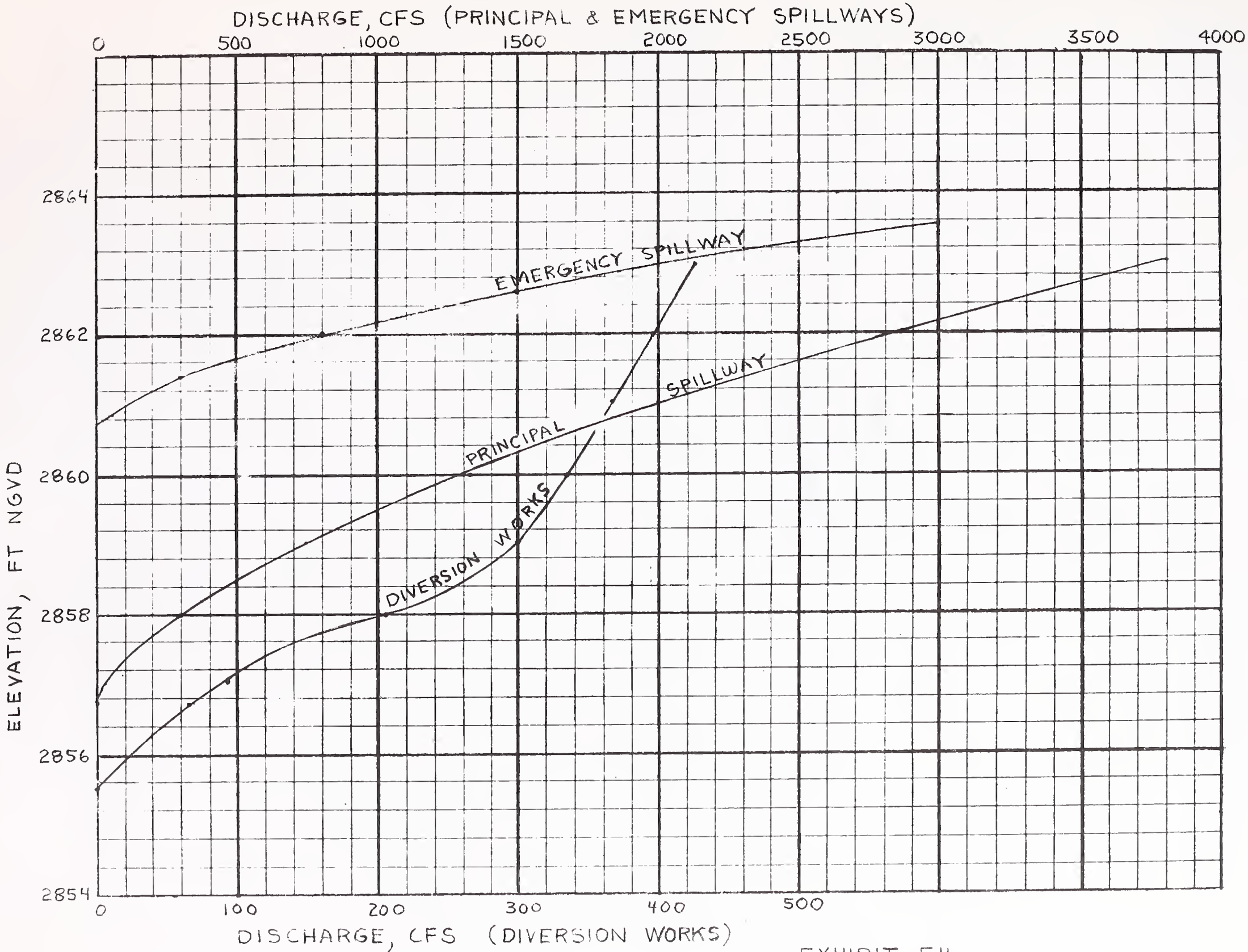


EXHIBIT E4
DISCHARGE RATING CURVES
SOUTH SANDSTONE CREEK DAM

APPENDIX F

CORRESPONDENCE

STATE OF MONTANA

DEPARTMENT OF FISH AND GAME

Helena, MT 59601
March 5, 1981

Mr. Sidney Knutson
Seattle District
Corps of Engineers
4735 East Marginal Way South
Seattle, Washington 98134

Dear Mr. Knutson:

We have the following comments to make regarding the safety analysis of South Sandstone Creek Dam:

Page ii - We disagree with the classification of the reservoir into the high hazard category. In our opinion, five inhabitable structures, only one of which lies above the confluence of South Sandstone and Sandstone Creek, involves only a few people. We don't believe the amount of economic loss can be classed as excessive either. Therefore, we believe the hazard classification should be significant instead of high.

Page iii - Apparently the author agrees with us as the term "significant" is used to describe the amount of property damage.

Page II - The statement is made that "information relative to project history . . . was very limited." No one came to either the Miles City regional office or the Helena headquarters of the Montana Department of Fish, Wildlife and Parks to check the pertinent files.

Page 14 - Shortly after the principal spillway was poured, the department became aware that the elevation was 0.35 feet below the intended level. Apparently the same discrepancy still exists. If any settling has occurred at the upper end of the spillway, it happened at the time of construction and has remainded stable since, or a construction error was made.

Page 23 - The term ". . . reasonably possible . . ." is used in relation to the probable maximum flood. Is it reasonable to attempt to predict the flooding which may occur throughout infinity? Nowhere have we ever seen any probability calculations on the PMF predictions. From the data available to us, it would appear that an attempt is being made to insure 100% safety. One Hundred percent safety is never economically possible.

Page 24 - Rainfall losses are assumed to be zero. This is apparently based on a presumption of frozen ground conditions. Yet, we are talking about a storm which is supposedly going to drop over 2 feet of moisture within a 72 hour period and have rapid times of concentration. For these factors to be met in eastern Montana, you have to be referring to a summer thunderstorm, otherwise you must take into consideration enough time for snow to melt.

The total runoff volume is stated as being 65,000 acre feet. Nowhere is there any indication of the maximum cubic feet per second which will be reached. With these kind of volumes, what elevation would the water reach at the dam location if no dam existed?

Page 41 - The dam is capable of discharging 5850 CFS according to your figures. This is approximately equal to the average flow of the Yellowstone River at Big Timber.

The time of concentration is not addressed anywhere in the report -- neither are total flows. Yet the statement is made that the dam will be overtopped at 8% of the PMF. How can this be determined without this data?

We appreciate this opportunity to review your document and anticipate your incorporating our comments.

Sincerely,

RON HOLLIDAY
Administrator
Parks Division

RH/gk
cc: Seaburg/Conklin
Dick Mayer

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

TED SCHWINDEN, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872 ADMINISTRATOR
(406) 449-3962 WATER RIGHTS BUREAU
(406) 449-2872 WATER SCIENCES BUREAU
(406) 449-2864 ENGINEERING BUREAU
(406) 449-2872 WATER PLANNING BUREAU

HELENA, MONTANA 59620

February 27, 1981

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Attn: Ralph Morrison

Re: HKM Associates Dam Safety Inspection Report on South Sandstone Creek Dam (MT-2005)

Dear Ralph:

We have reviewed the above referenced final draft report. We concur with the findings and recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report.

Thank you for the opportunity to review and comment on the final draft report on South Sandstone Creek Dam.

Sincerely,

Richard L Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB:AT:lj

United States Department of Agriculture
Soil Conservation Service
P.O. Box 970
Bozeman, MT
59715

March 9, 1981

Sidney Knutson, P.E.
Assistant Chief
Engineering Division
Seattle District Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Dear Mr. Knutson:

Thank you for the opportunity to review the final draft report on South Sandstone Creek Dam (MT 2005).

Our comments relating to specific report statements are:

Page 18, line 9, Page 42, line 8, Page 46, line 12, and photos 26 & 27: Plans and specifications did not call for an externally applied sealant or grout because the joints are designed to extend beyond the elastic limits of a crack sealant. The R-4 joints have an "O" ring rubber gasket to provide water-tightness and an expansion capability greater than 0.75 inch.

Page ii, line 24, and Page 26, first paragraph: Does the COE hydrology model consider channel storage?

Page 24, paragraph 2: Please give the type of storm, time of year, and the assumed ground conditions that resulted in zero infiltration.

General comments:

Repair plans are to be developed this spring. They presently include repair of the principal spillway box inlet, drains, and structural backfill. The diversion pipes will be reseated, aligned and regraded. The diversion outlet erosion will be repaired and protection added.

Erosion protection on the upstream face and in the stilling basin is deteriorating as expected, as only soft rock and gravels are locally available. The cost of importing hard rock riprap was not considered economical. Thus, frequent periodic maintenance is required.

We do not feel the meteorologic and hydrologic conditions used to develop the PMF are realistic. The conditions and criteria selected attempt to eliminate the element of risk to a degree that is not reasonable or practical.

We request that the meteorologic and hydrologic assumptions and conditions be fully presented and justified in the report.

We urge that a breach flood routing and thus a substantiated hazard classification be made in the Phase I inspection. With such a brief field overview,

general hydrologic modeling and a subjective hazard analysis, the report is forcing the, as yet unjustified, economic burden of a Phase II inspection on the dam owners.

Sincerely,

James S. Johnson

for Van K Haderlie
State Conservationist

cc:
Ray Smith, State Conservation Engineer, SCS, Bozeman
Dave Jones, Environmental Engineer, SCS, Bozeman